# INSTRUMENTS HANDBOOK

LEACH
CORPORATION

# INSTRUMENTS HANDBOOK

# LEACH CORPORATION
## CONTROLS DIVISION

## LEM Recorder
## (Astronaut's Memo Pad)
## Miniature Tape Recorder/Reproducer

Designed by Leach for Grumman Aircraft Engineering Corp.

- 10 hours recording time in 51 cubic inches
- Survival probability: 0.9998 for 10-hour mission
- Less than 3% p/p flutter @ 9g rms vibration




DESIGN REQUIREMENTS

Design a voice-actuated memo pad recorder for use by astronauts aboard the Apollo Lunar Excursion Module.

It must provide a total capacity of 10 hours recording time yet occupy an overall volume of less than 51 cubic inches. The weight is limited to 2.3 pounds and power consumption to 2.4 watts. Minimum acceptable probability of survival: 0.9965.*

It must perform with less than 3% p/p flutter while subjected to 15g acceleration; 52g, 11 ms, ½ sine shock (survival only); and 9g rms random vibration. It must also operate over pressure variations from sea level to hard vacuum, temperature from 0 to +160°F and combined salt fog, high humidity and exposure to 100% oxygen.

*Through the use of high reliability components and techniques, Leach increased the predicted survival probability to .9998 for the 10 hour... a 15 to 1 increase over the original requirement.

SPECIFICATION SUMMARY

| | |
|---|---|
| PURPOSE | Astronauts Memo Pad aboard Apollo Lunar Excursion Module Vehicle. |
| FUNCTION | Record only device with playback for go, no-go monitoring. |
| TAPE CAPACITY | 450 feet x ¼" wide. |
| SIZE | 6.22" x 2.05" x 4.0", 51 cubic inches |
| WEIGHT | 2.3 pounds. |
| POWER | 2.4 watts, 115 volts, single phase, 400 cps |
| HEAD GEOMETRY | 4 track interlaced. Record and Reproduce. |
| DATA CAPACITY | 1 channel for 10 hours using four tracks and head switching with bidirectional transport operation. |
| FREQUENCY RESPONSE OR BIT RATE | 300 – 5.2 kc with 300 – 3.0 kc audio, 4.4 kc ±5% Time code modulated FM carrier and 5.2 kc reference mixed. |
| SIGNAL TO NOISE RATIO | 35 db |
| DYNAMIC ENVIRONMENTS | 15g Acceleration<br>52g, 11 MS, ½ Sine Shock (survival only)<br>9g rms random vibration with 3% p/p flutter. |
| CLIMATIC ENVIRONMENTS | 0-160°F, hard vacuum, sand and dust, salt spray. |
| RELIABILITY REQUIREMENTS | 0.9998 for a 10 hour mission<br>Life – 5000 hours |

DATA CAPACITY, SIZE AND WEIGHT

The astronauts memo pad is an outstanding example of efficient utilization of available space, weight and power. Tape waste is minimized by VOX operation and a fast (50 ms) start time. The direct recording technique is used since it provides the highest packing density/inch of tape.

Through the judicious selection of modulation and multiplexing techniques, the unit records voice data from 300 cycles to 3 kc, a time code modulation FM carrier in the 4.1 kc to 4.7 kc range, and a 5.2 kc reference, all on a single track operating at a tape speed of 0.6 ips. While separate tracks for each would have permitted a slower tape speed, this would have reduced the signal to noise ratio on playback. The additional amplifiers required

would have added weight and power. Increasing the speed for reproduce would vary the time base and make the voice unintelligible.

The fast start time, already available for the voice operation, enables the recorder to provide rapid reversal and head switching with less than a 100 millisecond interruption at the end of each full tape pass. The operating speed of 0.6 ips provides 2.5 hours of record time per pass with the 450 feet of ½ mil tape in each cartridge. By providing logic for head switching and tape drive reversal, the record time was extended to 10 hours using four separate tracks in serial operation.

Cordwood construction and recently developed heat removal techniques permit the packaging of all record electronics in less than 13 cubic inches. This includes a direct record amplifier, time code input filter, voltage controlled oscillator, VCO output filter, reference oscillator, bias oscillator, power supplies, self test circuits and complex control logic.

The tape cartridge employs negator spring tensioning principles so that the tape is always under tension even with power removed or with the cartridge removed from the recorder. The cartridge provides physical protection of recorded tape and a convenient means of transferring the recorded information to the Leach-built ground reproduce equipment where audible voice and visual display of the time in days, hours, minutes and seconds is accomplished.

ENVIRONMENTAL RESISTANCE

The LEM voice and time recorder represents a significant advance in the state of the art for light weight, low speed tape operation in vibration environments. By employing dual capstans, a dynamically and statically balanced reeling assembly, a 2 phase hysteresis synchronous capstan drive motor and a rigidly controlled tape path, flutter is kept below 3% peak to peak. This specification is cumulative from DC to 1 kc while the equipment is being subjected to a 12.5g random vibration.

PERFORMANCE

It might be assumed that the combination of direct audio, multiplexed FM and multiplexed reference, all sharing the available direct record/reproduce dynamic range would reduce the quality or the integrity of the data. Yet design proof tests indicate that signal to noise on the audio channel is maintained at better than 35 db broad band over the 300 cps to 3 kc range. The integrity of the digital bits extracted from the FM carrier is adequate to ensure that no greater than 1 bit is missed in $10^6$. The 5.2 kc reference is used for the reproduce transport capstan servo control.

The controlled reproduce transport will correct speed errors of $\pm 25\%$ and flutter of 10% p/p so that time base stability for both the audio and the time correlation data is preserved. Tests were conducted by intentionally introducing errors up to these limits and results showed correction to within 1%.

FLEXIBILITY

The original device was intended to record multiplexed information on a single track when powered by single phase, 115 volts, 400 cps spacecraft power. It can also be modified to accommodate up to seven tracks, provide analog, digital, or FM record and reproduce and to operate from unregulated DC power. All this is accomplished without changing the transport design. The equipment has already demonstrated its ability to record up to 1000 bits/inch/track on four tracks with fewer than 3 in $10^7$ missed bits.

Conversion to an all digital multiple track record/reproduce device increases the weight to five pounds and the size to approximately 120 cubic inches. Power is increased to approximately 5 watts. This 2:1 increase in size, weight and power is primarily due to the additional signal conditioning (read/write) amplifiers and power conversion equipment. The data capacity of a device modified in this manner is over 46 million bits including parity and/or error correction bits.

# LEACH

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# LEACH CORPORATION
## CONTROLS DIVISION

Model MTR-1200
Miniature Tape Recorder

Model MTR-1200 is designed to record and store data with a high degree of reliability during severe conditions of shock and vibration. Tape capacity is 720 feet of 1 mil Mylar tape, making it especially suitable for use when long recording time is required. It will record in either direction and has an end-of-tape sensor.

Precision manufacturing insures consistent accuracy: recording heads are metal surfaced to reduce effects of temperature and extend head life.

This miniature tape transport is completely self-contained, requiring only external power for operation.



# Model MTR-1200
# Miniature Tape Recorder

## Data Acquisition And Storage For

Aircraft ■ Missile ■ Space ■ Nuclear Weapons ■ Rocket Sleds ■ Laboratory Tests ■ And other severe environmental applications.

## Mechanical Specifications

| | |
|---|---|
| Size | 10⅜" x 5⅞" x 4-9/16" |
| Weight | 13 pounds |
| Construction | Basic construction of aluminum casting |
| Mounting | Hard mount with four ¼-20 socket head cap screws |

## Environmental Specifications

| | |
|---|---|
| Vibration | 15g, 5 to 2000 cps (without shock mounting); 0.2" max. double amplitude |
| Shock | Recorder to withstand impact of 750g |
| Acceleration | 200g |
| Temperature | −20°F to +160°F |
| Humidity | 0 to 100% RH, with condensation |
| Altitude | Unlimited |

## Electrical Specifications

| | |
|---|---|
| Tape Speed | 3¾, 7½, 15, 30 or 60 ips (other speeds on special order) |
| Wow & Flutter | 2% p/p at 60 ips (measured under bench conditions) |
| Tape Capacity | 720 feet of 1 mil Mylar tape |
| Recording Time | 140 sec. at 60 ips |
| Tape Width | ½" or 1" |
| Magnetic Head Stacks | Three maximum, inline or staggered per IRIG specifications |
| Channels | 7, 14 or 16 standard; others on special order |
| Starting Time | Less than 1 second |
| Reversing Time | Less than 2 seconds at 15 ips |
| Power Requirements | 28v, 400 cps 2-phase power, approximately 56 watts Precision 400 cps inverters are available |

Subject to change without notice

## A Complete Line Of Compatible Electronics Is Available.

For your special recording requirements contact our factory or your nearest representative.

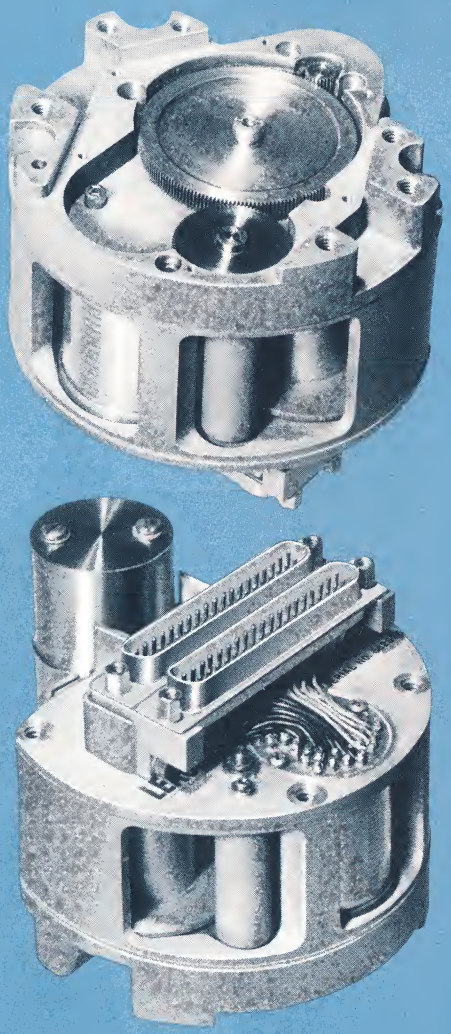
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# LEACH CORPORATION
## CONTROLS DIVISION

## Model MTR-362
## Miniature Tape Recorder



Model MTR-362 will record and store data with a high degree of reliability under extreme conditions of shock and vibration. Advanced design of this unit, including gear drive and silicon rubber pinch roller, permits operation in temperatures down to —40°F.

Weighing only 26 ounces, this miniature recorder will provide up to 14 channels of data. It is completely self-contained in a rugged, die cast housing and requires only external power for operation.

Precision manufacturing insures consistent accuracy: recording heads are metal-surfaced to reduce effects of temperature and extend head life.

Designed primarily to withstand high impact, this unit utilizes the analog or FM recording techniques with external electronics.

# Model MTR-362
# Miniature Tape Recorder

## Data Acquisition And Storage For

Impact Studies ■ High Velocity Launch ■ Atmospheric Re-entry ■ Ground Shock ■ Rocket Sleds ■ Water Entry ■ And other severe environmental applications.

## Environmental Specifications

| | |
|---|---|
| Vibration | 15g, 10 to 2000 cps; 0.3″ max. double amplitude |
| Shock | 2000g for 3 ms, any axis |
| Acceleration | 400g continuous |
| Temperature | −40°F to +160°F |
| Humidity | 0 to 100% RH |

## Mechanical Specifications

| | |
|---|---|
| Size | 3⅝″ dia. x 3⅛″ max. length |
| Weight | 26 ounces |
| Electrical Connector | Cannon DC-37P |

## Electrical Specifications

| | |
|---|---|
| Tape Speed | 3¾, 7½, 15 or 30 ips std. (other speeds on special order) |
| Wow & Flutter | Less than 1% RMS at 15 ips (measured under bench conditions) |
| Tape Capacity | 75 feet of 1 mil Mylar tape |
| Recording Time | One minute at 15 ips; proportional times at other speeds |
| Tape Width | ½″ or 1″ |
| Channels | 7 channels on ½″ tape or 14 channels on 1″ tape using inline construction |
| Starting Time | Less than 1 second |
| Power Requirements at 15 ips | 28v, 400 cps |

Subject to change without notice

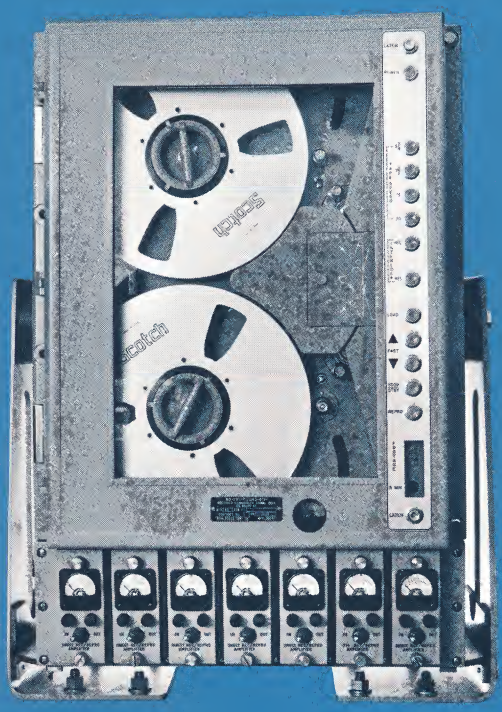
## A Complete Line Of Compatible Electronics Is Available.
## For your special recording requirements contact our factory or your nearest representative.

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# LEACH CORPORATION
## CONTROLS DIVISION



LEACH MTR-4200 RUGGED SHIPBOARD RECORDER
WITH HIGH SIGNAL TO NOISE PERFORMANCE

# leach shipboard recorder

*A rugged, shipboard recorder with outstanding high signal-to-noise performance has been developed by Leach Controls Division, specialists in high environmental recording systems.*

## COMPLETE CAPABILITY IN A RUGGED PACKAGE

The MTR-4200 was designed for use aboard ships and submarines for recording broadband, wide dynamic range analog signals from miscellaneous sources. It will record and/or reproduce seven (7) channels of Direct or FM data in strict accordance with IRIG standards for head geometry, tape speeds and bandwidths. Efficiently packaged, the MTR-4200 records and reproduces to the specified accuracy during exposure to the climatic, vibration and inclination environments of MIL-I-983 and after being subjected to hammer drop shock testing prescribed by MIL-S-901. Construction satisfys the maintainability standards of MIL-S-275 to allow field repair down to the component level.

*Tape Capacity:* ..... 1.0 mil thin oxide, ½" tape—4600 ft.
1.0 mil std. oxide, ½" tape—3600 ft.
1.5 mil std. oxide, ½" tape—2400 ft.
*Reel Size:* ..... 10½" NAB standard
*Tape Speeds:* ..... 3¾, 7½, 15 and 30 ips
*Head Geometry:* ..... 7 track interlace per IRIG 106-65
*Size:* ..... 30" X 22" X 14" maximum or 5.35 cubic feet
*Weight:* ..... 250 pounds maximum
*Power Required:* ..... 350 watts, 115 vac, 60 cps, single, phase
*Shock:* ..... withstands MIL-S-901 hammer drop test
*Vibration:* .... operates through MIL STD. 167 vibration
*Applicable Environmental Specs* ..... MIL-I-983
MIL-I-17623
MIL-S-901

## LOW NOISE PERFORMANCE IN ENVIRONMENTAL EXTREMES

Under the severe environments in which a shipboard recorder must operate, a high signal to noise ratio coupled with a full range of recording capability is the major requirement. Every system element and all interconnections must be considered as a possible noise source or potential pickup point. The MTR-4200 incorporates many new features which result in a record/reproduce system with 75 db signal to noise ratio at even the most critical power source frequency of 60 cps.

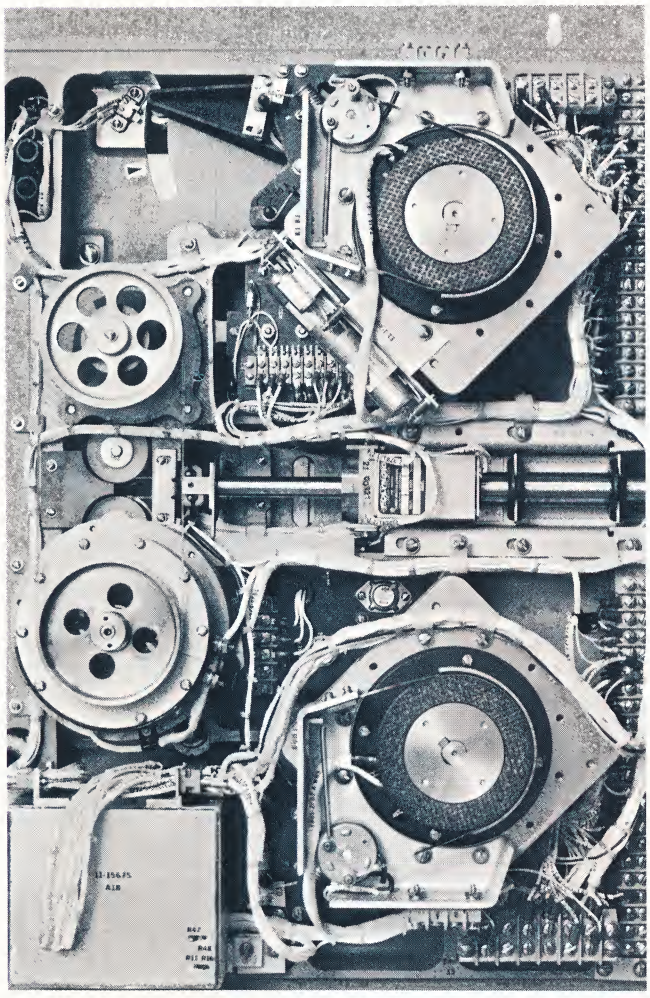
Both FM and Direct input capability is maximized. In the case of FM, full range recording is accomplished with an input of as little as 0.5 volts p/p. In direct recording, the system provides extremely high signal to noise performance with as little as 10 millivolts or as much as 0.5 volts for full range recording. All direct inputs and outputs are transformer coupled and balanced to provide isolation from input and output lines.

A Leach designed low mass servo-controlled capstan drive insures a long term time base stability of 0.01% and peak to peak flutter is maintained below 0.35%—both important factors in the identification of irregularities in the sound spectrum.

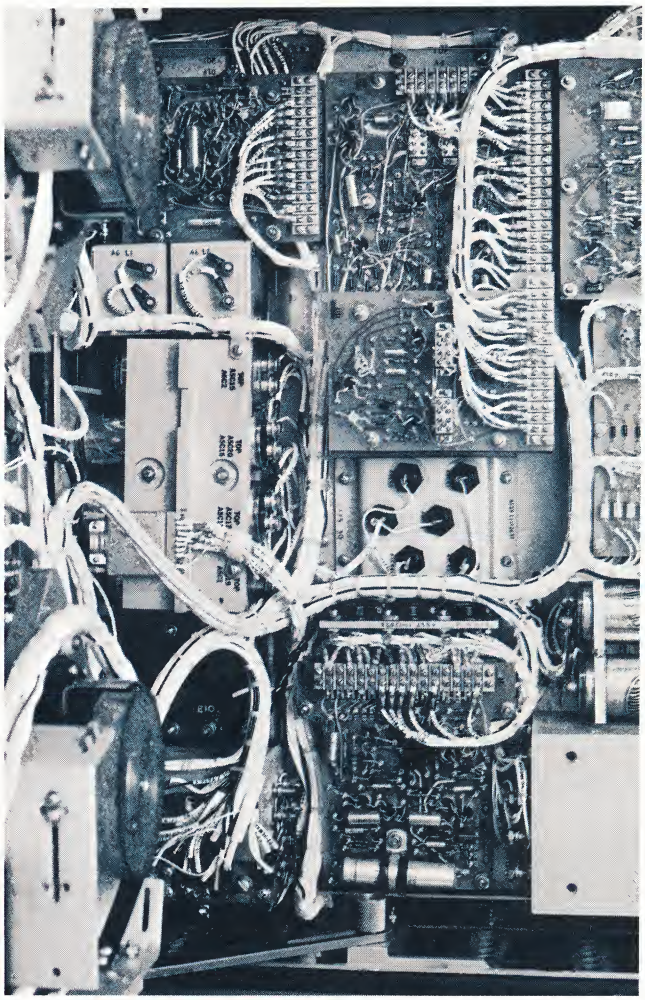
*Frequency Response:*
*Direct* ..... 50 cps to 60 kc, ± 2 db at 30 ips
*Record/Reproduce* ..... 50 cps to 30 kc, ± 2 db at 15 ips
40 cps to 15 kc, ± 2 db at 7½ ips
40 cps to 7.5 kc, ± 2 db at 3¾ ips
*FM Record/Reproduce* ..... DC to 5 kc, ± 0.5 db at 30 ips
DC to 2.5 kc, ± 0.5 db at 15 ips
DC to 1.25 kc, ± 0.5 db at 7½ ips
DC to .625 kc, ± 0.5 db at 3¾ ips
*Signal to Noise Ratio:*
*Direct* ..... 40 db broadband or 75 db/cycle @ 2% distortion
*FM* ..... 48 db broadband @ 1% distortion
*Flutter* ..... 0.4%, DC to 3 kc under environment




*Unique record/reproduce amplifier design using silicon semiconductors allow 75db signal-to-noise ratio even at the most critical frequency of 60 cps.*



*Tape transport incorporates specially designed low mass, servo-controlled capstan drive system and new shielding techniques to meet extreme operational requirements.*



*All solid-state electronics allow extremely high signal-to-noise performance with very low level signals. Electroencephalogram instrumentation techniques are used to overcome noise problems from screw terminal barrier strips.*

## Capabilities

From this modern facility have come data storage equipment for complex programs such as: Project Apollo, Discoverer/Agena Satellites, LEM (Lunar Excursion Module), Project Saturn, the Polaris Program, and many classified military projects.

The range and variety of the projects has been extraordinary. Each development contract was a challenge and an inquiry into entirely new areas. Both resulted in the improvement of subsequent systems. The improvements, in turn, have boosted the growth and expanded the capabilities of the Controls Division.

One group, the Development Staff, was independently organized to investigate and implement new techniques in all phases of high-reliability tape recordings. Not only are circuit and logic designs refined for new specifications, but hardware and related production processes are developed for each application.

If you have an application with special specifications or extreme environmental problems, tell us. We'll examine it in detail, and propose the precise equipment for the exact solution.

At Leach, Controls Division, leadership in new technology assures continued growth and quality products.

## Facilities

The Controls Division of Leach Corporation is one of the nation's foremost developers and manufacturers of high environmental aerospace and industrial data acquisition and recording equipment. In a facility of 70,000 square feet, advanced systems are designed and built for space, geophysical, and oceanographic applications.

Here also, more than 450 Leach people contribute to the advancement of scientific research, safety standards and the exploration of man's physical environment, simulated in fully equipped test laboratories.




*Precision assembly area.*



*"White room" for the ultimate in contaminant-free assembly.*

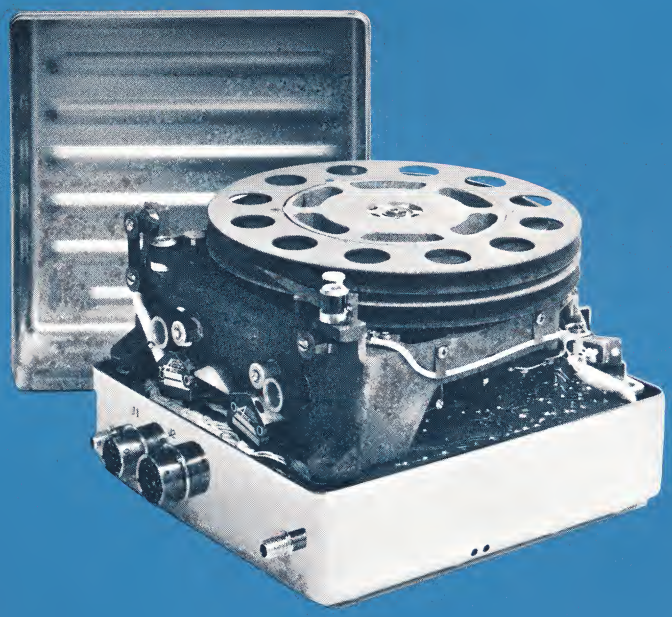
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Bulletin MTR-4200 766

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# LEACH CORPORATION
## CONTROLS DIVISION



# LEACH SATELLITE TAPE RECORDERS — SERIES 2000

# leach satellite recorders

*Leach Controls Division, first in the design and manufacture of Satellite Tape Recorders, has logged an impressive record of accomplishments in support of major United States Space Programs. Today, over 85% of all Satellite Recorders are Leach built. Twenty different types in over 30,000 hours of operation have successfully accomplished more than 100 missions.*

## CUSTOM DESIGNED TO PROVIDE EFFICIENT PERFORMANCE

The original tape transport for satellite applications was designed by Leach to collect data during one or more orbits of the earth, and upon interrogation, to release the data in a burst through a high speed playback system. Small size, low weight and minimum power consumption are requirements of the application.

### Basic Mechanical Specifications:

*Tape Capacity (0.65 mil)*.....3000 ft.
*(1.08 mil)*.....1900 ft.
*(1.5 mil)*.....1200 ft.
*Tape Width*.....¼ inch
*Number of Tracks*.....Two (2) standard; up to 4 on special order
*Tape Speeds Available*.....0.5 to 100 ips
*Speed Regulation*.....±0.5%
*Reproduce/Record Ratios*.....Up to 200/1
*Direction of Operation*.....Bi-directional (reproduce in either direction)
*Modes*.....Record, Reproduce, Rewind
*Controls*.....Remotely controlled
*Size*.....7.6″x7.1″x5.312″ (290 in³)
*Weight*.....10 to 15 pounds
*Power*.....22 to 30 volts DC, 5 to 25 watts depending on tape speed

## CUSTOM DESIGNED TO INSURE FAILURE-FREE LONG LIFE

Rugged construction of the Series 200 recorders insures non-operating survival during the most severe launch environments. Precision assembly and hermetic sealing provides operating life of up to one year in orbit. All components are space qualified and approved. The Model 2200 recorder has been fully tested for reliable operation after radiation exposure of up to $-1 \times 10^{13}$ neutrons per cm² and $1 \times 10^{8}$ carbon rads.

### Environmental Specifications

*Operating—*
*Temperature*.....0° to 130° F
*Altitude*.....Unlimited
*Acceleration*.....0g (orbital) to 1g
*Survival—Rocket Launch (Agena, Delta, Scout)*
*Temperature*.....−30°F to +165°F
*Acceleration*.....11. 6g
*Shock*.....40g. 6 msec.
*Vibration, sine*.....3g from 14 to 40 cps
7.5g from 40 to 400 cps
15g from 400 to 3000 cps
*Acoustic*.....145 db, 37.5 to 9600 cps
*MTBF*.....14,000 hours

## CUSTOM DESIGNED FOR FLEXIBILITY IN DATA PROGRAMMING

Most important in the design of the Series 2000 was provision for modification in data requirements. Multiple head stacks and signal conditioning electronics, interfaced with the record and reproduce heads, accomodate PAM/FM, Direct, Single carrier FM, Multiplex FM, PDM and digital data in various combinations and over a wide rate range.

To date, using the original tape transport as a nucleus, over 20 different types have successfully accomplished their mission. Many other electronic options can be supplied on special order.

### Analog Systems

*Input Frequency*.....200 cps - 150 kcps
*Input Level*.....1 V rms
*Impedance*.....200 K ohms minimum shunted by 100 pf
*Output Frequency*.....400 cps - 150 Kcps ± 3 db
*Level*.....1 V rms
*Impedance*.....1000 ohms maximum
*Signal/noise*.....30 db rms to rms
*Distortion*.....3% from 0° to 85° F
5% from 85° to 130° F

### FM Systems

*Input Frequency*.....DC to 975 cps sine
DC to 120 cps square
*Level*.....0 to 5.3 volts peak
*Impedance*.....200 K ohms minimum
*Output Frequency*.....DC to 3900 cps sine
DC to 480 cps square
*Level*.....0 to 5.3 volts peak
*Impedance*.....1000 ohms maximum
*Signal/noise*.....30 db peak to peak
*Linearity*.....± 0.1 volts
*Rise time*.....100 microseconds
*Overshoot*.....5% maximum

### Digital Systems

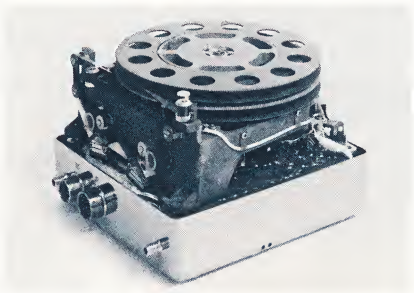
*Recording Technique*.....Manchester Code
*Input Data Rate*.....Up to 100K bit/sec./track at 50 ips

NOTE: Specifications subject to change without notice.

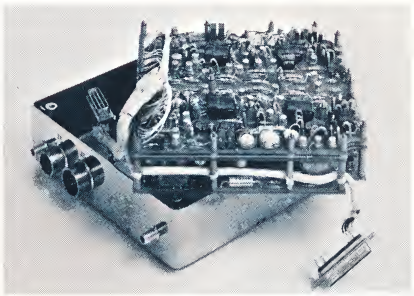
*Impedance*.....20K ohms minimum
*Level*.....“1” = 6 ± 0.5 V
“0” = 0 ± 0.5 V
*Output Data Rate*.....200K bit/sec./maximum at 100 ips
*Level*.....“1” = 6 ± 0.5 V
“0” = 0 ± 0.5 V
*Impedance*.....600 ohms
*Pack Density*.....200 bits/inch/track
*Error Rate*.....Less than 1 in $10^6$
*Bit Jitter*.....± 1% of bit period

**Megacycle Systems**

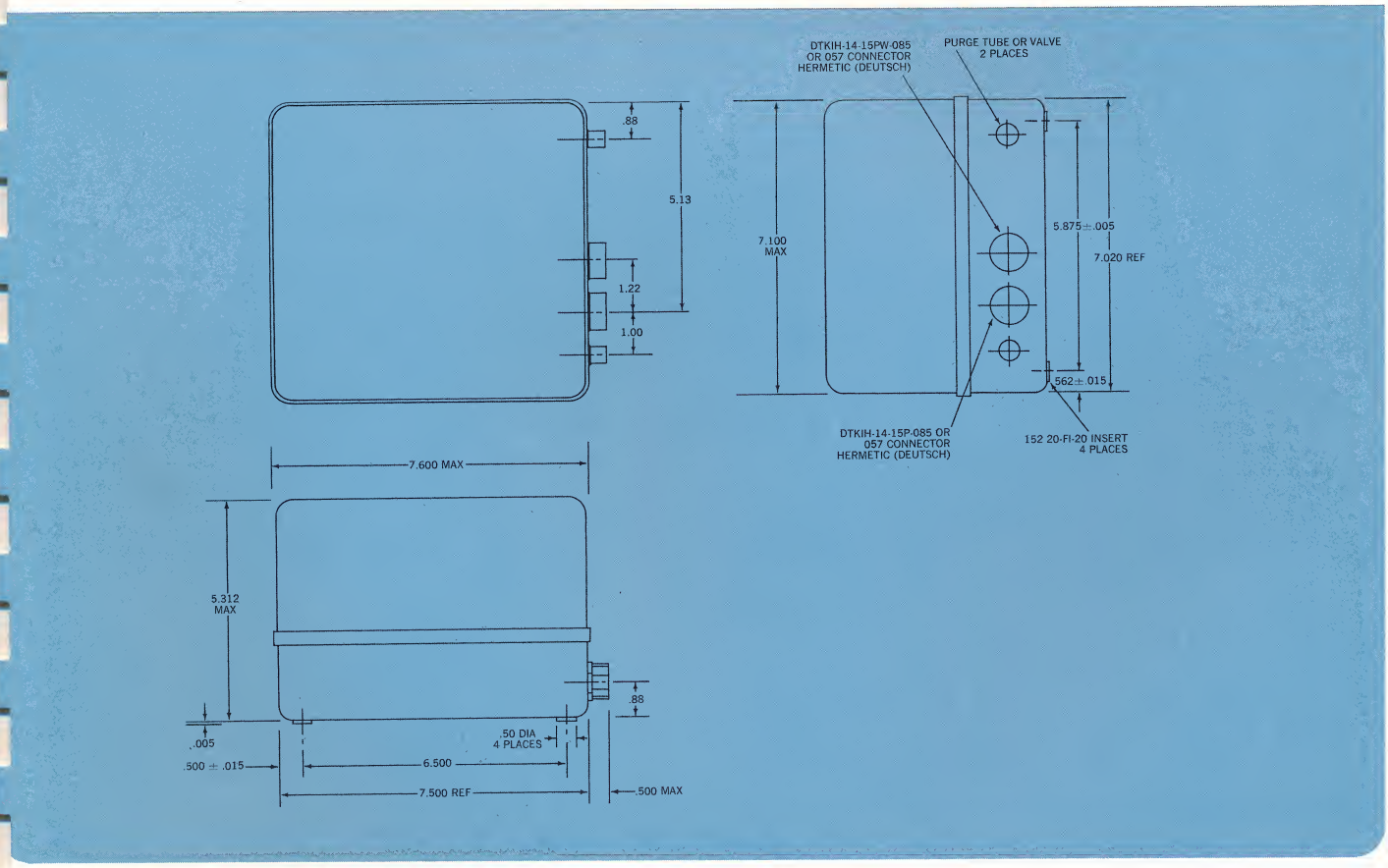
*Input Frequency*.....250 Kc, 500Kc, 1 megacycle
*Level*.....3V peak to peak
*Impedance*.....200 ohms
*Output Frequency*.....1 Kc to 1 megacycle ± 3 db
*Level*.....3 volts peak to peak
*Impedance*.....50 ohms
*Signal/Noise*.....Better than 26 db rms broadband
*Distortion*.....3% maximum @ 10 Kc
*Envelope Delay (Phase distortion)*.....less than 0.2 microseconds from 100 Kc to 1Mc
*Crosstalk*.....—30 db maximum



*Open view of recorder showing compact, rugged packaging*



*Record/reproduce electronics packaged on card file*



# LEACH CORPORATION
## CONTROLS DIVISION



# LEACH TAPE RECORDER/REPRODUCER MTR-3200

For instrumentation quality performance in critical environments

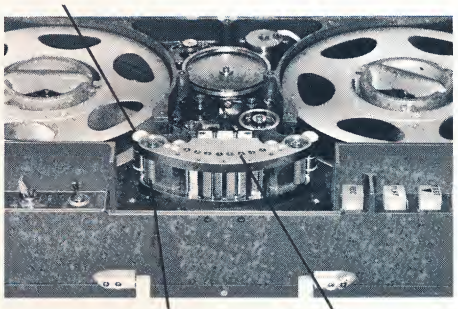
**LEACH CONTROLS DIVISION,** *specialists in high environmental data acquisition, storage and playback, have combined the optimum performance characteristics necessary for precision recording and playback, packaging them in one small, efficient unit. Now, in stringent environments — or in the lab — no other instrumentation recorder/reproducer quite matches the performance of the Leach MTR-3200.*

# designed for reliability

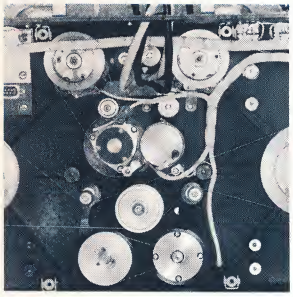
Rugged construction of the MTR-3200 guarantees the most precise recording, storage and reproduction of data collected in extreme environments. Mil type components are used throughout the unit and numerous special design features insure overall reliability. For instance, through the use of "dual differential" capstan drive to control tape tension, pinch rollers and their associated problems are eliminated. Flutter, as a result, is held to less than 0.5% peak-to-peak at 60 ips.

Thus, the MTR-3200 is ideally suited for use in experimental aircraft, missiles, orbiting vehicles, drop tests, measuring blast created pressure wave fronts, nuclear effects testing, and other critical applications.

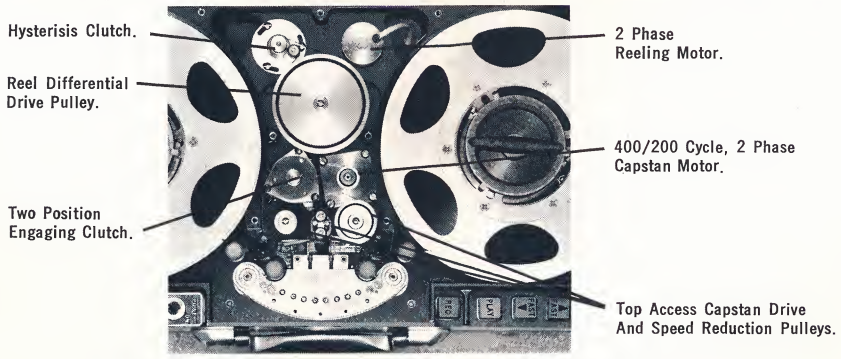
| | |
|---|---|
| *Shock* | 10g - 11 ms ½ sine - 3% p/p flutter<br>25g - 8 ms ½ sine - 5% p/p flutter |
| *Vibration* | 10 g rms random operating - 6% p/p flutter<br>10 g peak - 5 cps to 2000 cps.<br>At resonant points, 6% p/p flutter |
| *Flutter* | Less than 0.5% peak-to-peak<br>DC to 10 KCS at 60 ips 0.1% rms<br>cumulative 0.1 cps to 300 cps |
| *Acceleration* | 25 g operating<br>100 g non-operating |
| *Temperature* | 0°C to +71°C operating<br>(−55°C with internal heaters) |
| *Humidity* | 95% operating<br>100% with condensation<br>non-operating |
| *Altitude* | 150,000 ft. (unlimited for 20 hours) |




*Unique tape drive provides optimum tape tension through extreme vibration and shock.*



*Space-Proven mylar belts transfer power smoothly and efficiently through extremes of temperature and humidity.*




*Precision capstan and reeling drive assemblies assure gentle tape handling under all operating conditions.*

# designed for versatility

In the MTR-3200, plug-in modular electronic construction facilitates selection of recording modes and tape speeds and makes possible numerous record/reproduce options. This unique instrumentation recorder provides up to 14 channels Analog (direct) and FM or 16 Digital channels, which can be used in any combination. Seven tape speeds are available, and with a simple belt change, are electrically selectable in speed pairs.

Ample tape capacity of 2,400′ is standard, and specialized bi-directional operation allows extended recording time.

Minimum power required for operation, and local or remote control, make the MTR-3200 suitable for use at any test site.

Standard NAB reels used on the MTR-3200 can be conveniently interchanged with those used on the standard ground station. In fact, the entire unit is designed to be compatible with IRIG standard data reduction equipment.

A Remote Control Unit, furnished with cable assembly, is easily connected with the MTR-3200 Recorder. Optionally, a visual indication of tape position is available on the Remote Unit. Thus, it is possible to determine approximate locations on the tape as well as the amount of tape remaining on the supply reel regardless of tape thickness, reel size and tape length.

*Record/Reproduce Modes*.....Analog (direct), FM, Digital

*Tape Capacity* (1 mil tape, thin oxide)....2400 feet
(1 mil tape, std. oxide)....1800 feet
(1.5 mil tape, std. oxide)..1250 feet

*Reel Size*.....8″ Standard NAB Reels

*Tape Speeds*.....Standards are: (1⅞-3¾) (7½-15) (30-60) with any pairs electrically selectable. Fast forward and rewind is 120 ips. Optional speeds range from 0.5 ips to 240 ips

*Tape Widths*.....½″ and 1″

*Number of Tracks*.....Up to 14 Direct, FM record/reproduce. Up to 16 Digital record/reproduce. Up to 32 Digital record on 1″ tape on special order

*Speed Regulation*.....Within 0.25%

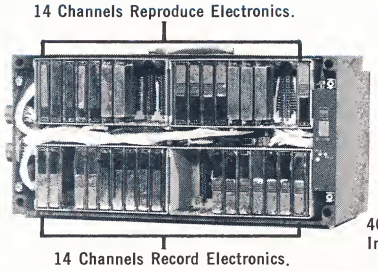
*Start or Stop Time*.....Less than 1 second at 60 ips Better at lower speeds

*Power Requirements*.....70 watts - 28 VDC
*(Full 14 channel system)* (25 - 32 VDC)
Operation from 60 cps—115-220 VAC and 400 cps with auxiliary power supply

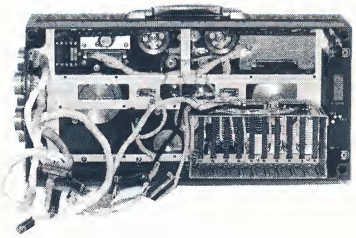
*Direction of Operation*.....Equal accuracy with record or reproduce in both directions

*Function Controls*.....Record and/or reproduce, fast forward, fast reverse, stop

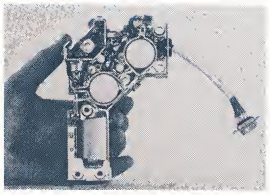
*Mode Controls*.....High/low speed selection, forward/reverse, power on/off (circuit breaker)



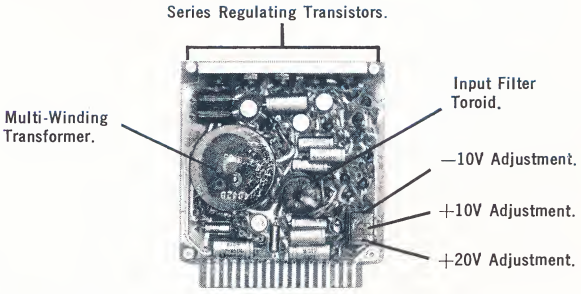

*Compact packaging of interchangeable modular electronics provides flexibility in record/reproduce channel assignments.*



*Module housings readily removable for access to transport components.*



*System pre-regulator high efficiency pulse width regulator accepts raw 28 VDC input—provides regulated output of 19 VDC to power all subsequent system electronics.*




*Multiple Voltage Regulator ■ accepts 19vdc and provides regulated voltages for operation of record/reproduce electronics. Will drive up to 16 record modules.*



# designed for maximum performance

The MTR-3200 offers a wide range of "extra"capabilities. For example, data bandwidths are extended beyond standard IRIG requirements and, on special order, extended broadband FM recording and reproduction is available.

In both Analog and FM, input and output level controls are independently adjustable for each channel, and reproduce amplifiers include adjustable equalization to accommodate tape differences.

Efficient digital recording provides low bit dropout error and low jitter. Special Analog to Digital, Serial to Parallel and Parallel to Serial Conversion equipment can be supplied to be compatible with the standard digital electronics.

In addition, skew correction to clock out signals from parallel channels is available as an optional plug-in card.

Low level DC amplifiers are available to precondition transducer and similar signals for conventional recording levels. These DC amplifiers can be obtained complete with gage supplies and zero offset adjustments.

On special order, many other electronic options can be supplied to meet specific application requirements.

### Direct record/reproduce

Frequency Response and Signal to Noise Ratio:

| Tape Speed | Standard Bandwidth ±3 db | S/N | Extended Bandwidth ±3 db | S/N |
|---|---|---|---|---|
| 60 | 100 cps-100 kcs | 38 db | 300 cps-250 kcs | 32 db |
| 30 | 100 cps-50 kcs | 38 db | 300 cps-125 kcs | 32 db |
| 15 | 100 cps-25 kcs | 36 db | 300 cps-62.5 kcs | 30 db |
| 7½ | 50 cps-12.5 kcs | 36 db | 300 cps-31.25 kcs | 30 db |
| 3¾ | 50 cps-6.25 kcs | 34 db | 300 cps-15.625 kcs | 28 db |
| 1⅞ | 50 cps-3.125 kcs | 34 db | 300 cps-7.812 kcs | 28 db |

*Input Sensitivity*.....0.5 v rms to 5.0 v rms
*Input Impedance*.....100 KΩ minimum
*Distortion*.....1% third harmonic at normal record level
*Output Impedance*.....600Ω maximum
*Output Level*..... 5.0 volts p/p

### FM record/reproduce

Frequency Response and Signal to Noise Ratio:

| Tape Speed | Carrier | Standard Bandwidth | S/N | Carrier | Extended Bandwidth | S/N |
|---|---|---|---|---|---|---|
| 60 ips | 54 kc | DC-10 kc | 42 db | 108 kc | DC-20 kc | 42 db |
| 30 ips | 27 kc | DC-5 kc | 42 db | 54 kc | DC-10 kc | 42 db |
| 15 ips | 13.5 kc | DC-2.5 kc | 40 db | 27 kc | DC-5 kc | 40 db |
| 7½ ips | 6.75 kc | DC-1.25 kc | 40 db | 13.5 kc | DC-2.5 kc | 40 db |
| 3¾ ips | 3.375 kc | DC-.625 kc | 38 db | 6.75 kc | DC-1.25 kc | 38 db |
| 1⅞ ips | 1.687 kc | DC-.312 kc | 38 db | 3.375 kc | DC-.625 kc | 38 db |

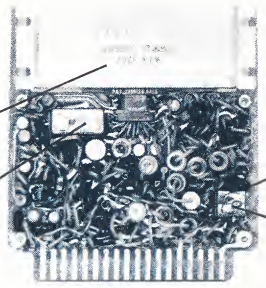
NOTE: Specifications Subject to Change Without Notice

*Input Sensitivity*.....0.5 v p/p to 5.0 v p/p
*Input Impendance*.....100 KΩ minimum
*Output Level*.....5.0 v p/p
*Output Impedance*.....600Ω maximum
*Linearity*.....1.0% of best straight line
*Center Frequency Stability*.....0.5% long term under environment
*Record Amplifier Center Frequency*.....Plug-in networks, electrically selectable, are available in adjacent speed pairs
*Reproduce Amplifier Center Frequency & Filter*.....Plug-in networks, electrically selectable, are available in adjacent speed pairs

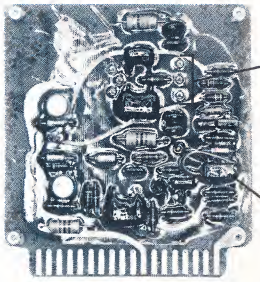
### Digital record/reproduce

*Recording Technique*.....NRZI, NRZ change
Others on special order
*Maximum Data Rate* .....180 K bit/sec/track
(dependent on tape speeds and number of channels)
*Single Track Bit Drop Out Error*
@ 1000 bit/inch — less than 2 bits in $10^6$
@ 400 bit/inch — less than 4 bits in $10^7$
*Input Impedance*.....20 K Ω minimum
*Input Level*.....Binary "1" 6 VDC ± 0.5V
Binary "0" 0 VDC ± 0.5V
Other levels available on order
*Output Impedance*.....600 Ω maximum
*Output Level*..... Binary "1" 6 VDC ± 0.5V
Binary "0" 0 VDC ± 0.5V
Other levels available on order
*Interchannel Timing Error at 60 ips*.....10 microseconds maximum
*Bit Jitter at 60 ips*.....± 3% NRZ bit period
*Rise and Fall Time*.....1.0 microseconds maximum

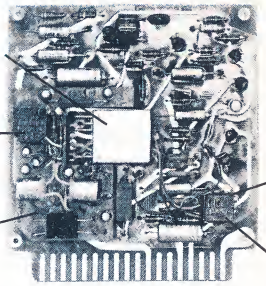




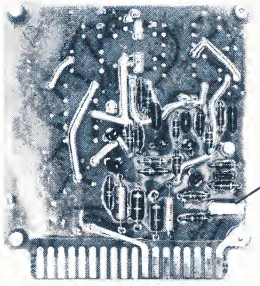

*FM Reproduce Amplifier ■ low noise reproduce circuit with frequency doubling detector and efficient low pass filter provide optimized response and outstanding S/N ratio.*



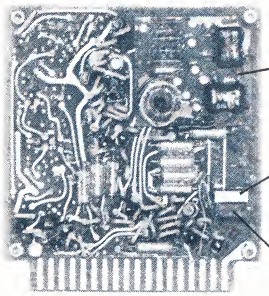

*Analog Bias Oscillator ■ supplies 350 kc or 800 kc bias drive to all direct record amplifiers up to 14 channels.*



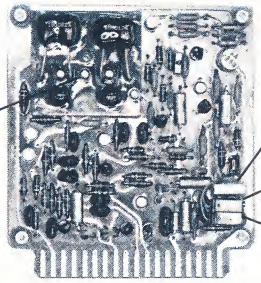

*Direct Reproduce Amplifier ■ universal circuitry as in record amplifier features low noise pre-amp with outstanding S/N ratio*




*Digital Record Amplifier—NRZ Mark*




*Digital Reproduce Amplifier ■ universal reproduce amplifier capable of handling NRZ-mark or NRZ-change with provisions for skew correction*




*FM Record Amplifier ■ extremely linear voltage control oscillator (within 0.5%) at full (40%) deviation*

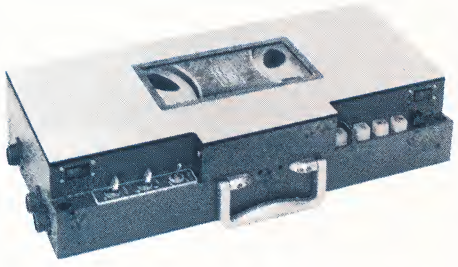


# designed for convenience

Compact and lightweight, the MTR-3200 is easily hand-carried out in the field, occupies minimum space in airborne vehicles or fits conveniently in standard laboratory racks. Simplicity in design of the unit, particularly in such operations as tape threading, minimizes the chance of error by inexperienced operators. "Failsafe" push-button controls are mounted on the front panel for operating ease.

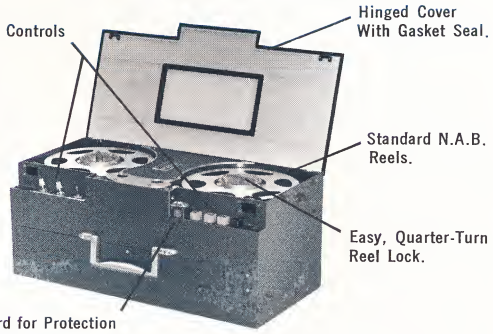
The MTR-3200 transport and recording heads are also available as a "space saving" unit independent of the associated electronics which can be located elsewhere in a separate housing.

| | |
|---|---|
| *Size* | 8.625″x9.5″x20″ (including all electronics for 14 or 16 channel record and reproduce, excluding connectors) |
| *Volume* | 1,639 cubic inches |
| *Weight* | 54 lbs. maximum (including electronics and tape) |
| *Mounting* | Hard mount to 20″x9.5″ flat surface with ¼-20 bolts (Rack mounting adaptors available) |

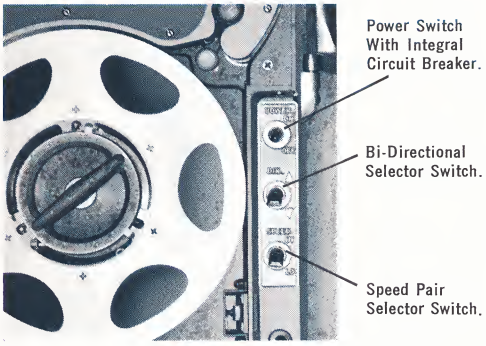




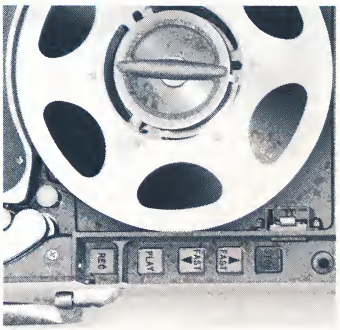
*Permanent pictorial layout of electronic adjustments and test points.*



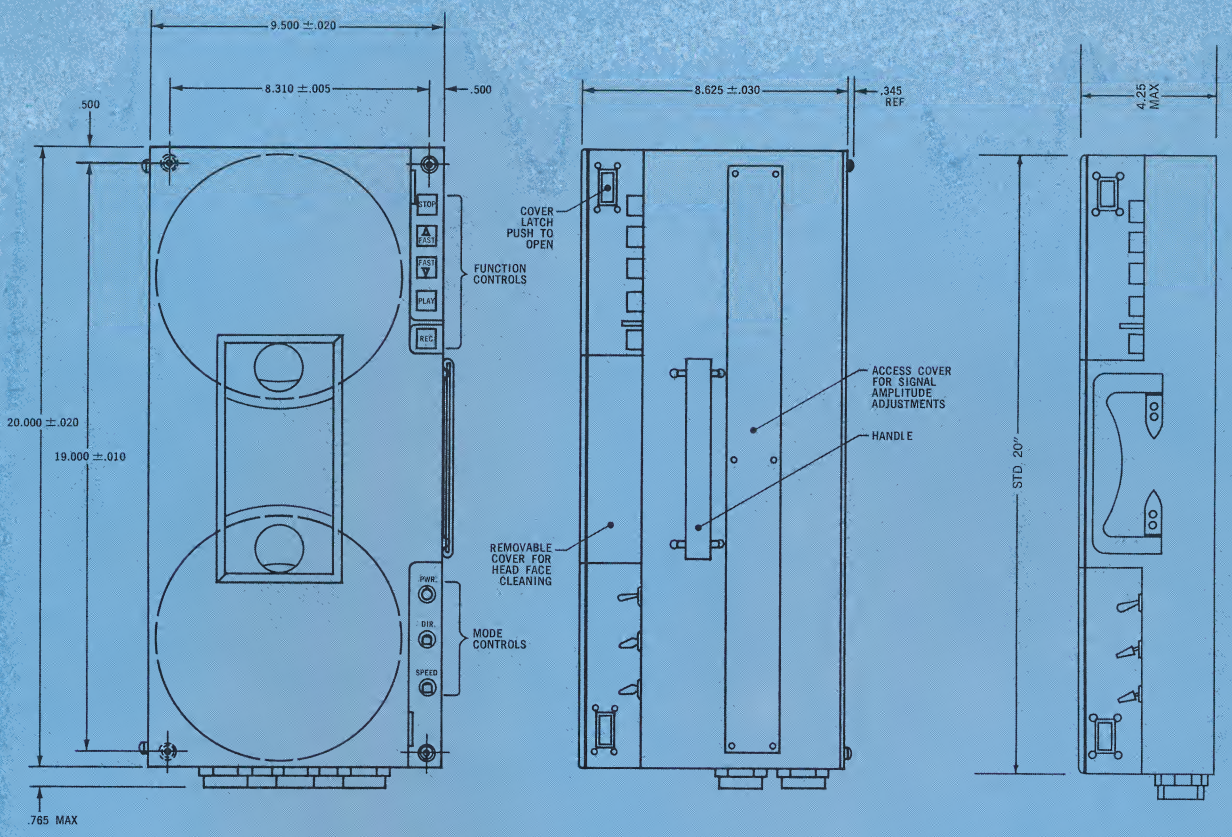

*Rugged, single-frame construction.*

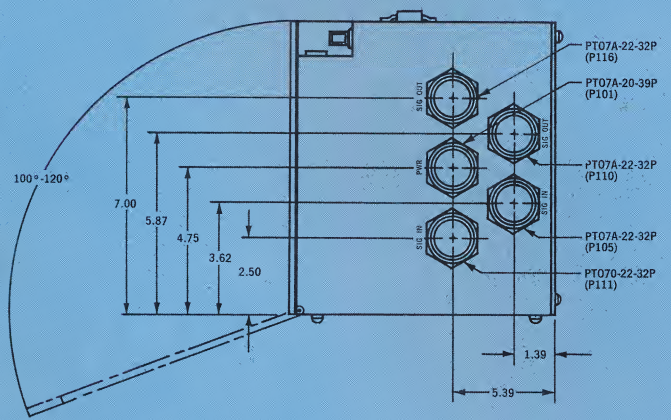


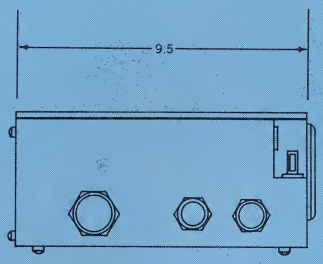

*Foolproof primary operating controls.*



*Illuminated, momentary contact switches for all functional controls.*


9.500 ±.020
8.310 ±.005
.500
500
20.000 ±.020
19.000 ±.010
.765 MAX
STOP
FAST
FAST
PLAY
REC
FUNCTION CONTROLS
PWR
DIR
SPEED
MODE CONTROLS
8.625 ±.030
.345 REF
COVER LATCH PUSH TO OPEN
ACCESS COVER FOR SIGNAL AMPLITUDE ADJUSTMENTS
HANDLE
REMOVABLE COVER FOR HEAD FACE CLEANING
4.25 MAX
STD. 20"


100°-120°
7.00
5.87
4.75
3.62
2.50
SIG OUT
PWR
SIG IN
SIG OUT
SIG IN
PT07A-22-32P (P116)
PT07A-20-39P (P101)
PT07A-22-32P (P110)
PT07A-22-32P (P105)
PT070-22-32P (P111)
1.39
5.39


9.5

## MTR-3200 APPLICATIONS

The MTR-3200 has won wide acceptance throughout industry for a variety of applications. This is best illustrated by the following partial list of users and applications.

| *Customer* | *Application* |
|---|---|
| Lockheed | Aircraft Flight Test |
| U.S. Navy | Ship Model Testing |
| Australian Government | Missile Flight Test |
| Marcel Dassault | Aircraft Instrumentation |
| Compagnie Generale de Geophysique | Seismic Exploration |
| Ford Motor Company | Auto Vehicle Test |
| United Geophysical Corp. | Geophysical Exploration |
| Volkswagenwerke | Experimental Auto |
| NASA/Ames | Experimental Data Acquisition |
| Wright-Patterson AFB | Experimental Flight Test |
| Hughes Aircraft Company | Helicopter Flight Test |
| General Dynamics Fort Worth, Texas | F-111 Test |
| Curtiss-Wright Corporation | VTOL Instrumentation |
| Electronique Marcel Dassault | Flight Test |
| NASA, Edwards AFB | Flight Test |
| Teledyne Systems | Integrated Helicopter Avionics System Flight Test |
| Sandia Corporation | Geophysical Data |

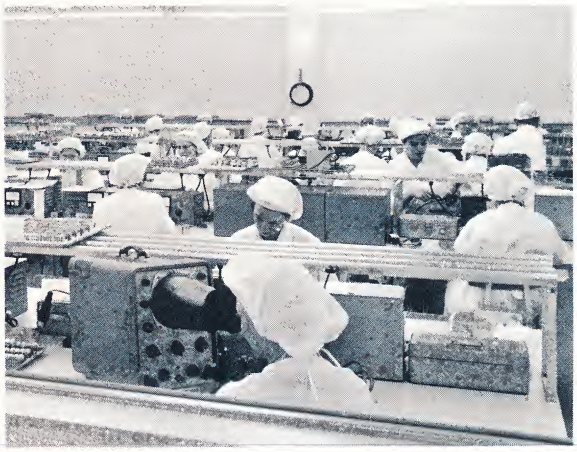
### Facilities

The Controls Division of Leach Corporation is one of the nation's foremost developers and manufacturers of high environmental aerospace and industrial data acquisition and recording equipment. In a facility of 70,000 square feet, advanced systems are designed and built for space, geophysical, and oceanographic applications.

Here also, more than 450 Leach people contribute to the advancement of scientific research, safety standards and the exploration of man's physical environment, simulated in fully equipped test laboratories.




*Precision assembly area*



*"White room" for the ultimate in contaminant-free assembly.*

# LEACH

**LEACH CORPORATION CONTROLS DIVISION:** 717 North Coney Avenue, Azuza, California, Phone: (213) 334-8211, Export: LEACH INTERNATIONAL, S.A.

## ANALOG RECORD AMPLIFIER (32-ARA-800-S and 800-E)
## GENERAL DESCRIPTION

The Analog Record Amplifier records data information onto the magnetic tape in direct proportion to the information received at the input. The input information is amplified and pre-conditioned to a level adequate to drive the magnetic record head. In addition, the analog information is linearly mixed with a bias signal. The bias signal is utilized to overcome the hysteresis non-linearity of the magnetic tape.

The frequency response of the Analog Record Amplifier, in conjunction with magnetic recordings, is dependent upon tape speed. The nominal tape speeds for standard operation are in speed pairs of: 60/30 ips, 15/7.5 ips, and 3-3/4 / 1-7/8 ips. The Analog Record Amplifier can be utilized with either standard bandwidth recordings or double bandwidth recordings. Standard bandwidth recording and double bandwidth recording frequency response are tabulated in Table I.

TABLE I

| STANDARD BANDWIDTH RECORDINGS | |
|---|---|
| Tape Speed in ips | Frequency Response |
| 60/30 | 100 cps - 100 kcs<br>100 cps - 50 cks |
| 15/7.5 | 100 cps - 25 kcs<br>50 cps - 12.5 kcs |
| 3.75/1.875 | 50 cps - 6.25 kcs<br>50 cps - 3.125 kcs |
| **DOUBLE BANDWIDTH RECORDINGS** | |
| Tape Speed in ips | Frequency Response |
| 60/30 | 300 cps - 250 kcs<br>300 cps - 125 kcs |
| 15/7.5 | 300 cps - 62.5 kcs<br>300 cps - 31.25 kcs |
| 3.75/1.875 | 300 cps - 15.625 kcs<br>300 cps - 7.812 kcs |

The Analog Record Amplifier is designed to operate with either standard frequency bias or double frequency bias. The standard bias frequency is 350 kc; the double bandwidth bias frequency is 800 kc. The Analog Record Amplifier can be changed from one mode of operation to the other by changing a pair of jumper leads. The bias frequencies used in analog recordings are always at least three times greater than the highest data frequency.

In addition to the data signal input and bias input for the Analog Record Amplifier, provision is made to record a reference frequency. The reference frequency is often used in the playback of analog information to compensate the data recorded. All the Analog Record Amplifiers can be driven by a common Reference Frequency Oscillator. The reference frequency is usually the highest frequency the analog system can record consistent with tape speed. As the tape speed is switched, the frequency of the reference input is changed to be consistent with the bandwidth recording available.

## PERFORMANCE SPECIFICATIONS

The following table gives the available frequency response for standard and double bandwidth analog recordings at the six standard tape speeds. The record amplitude response of the Analog Record Amplifier through the bandwidths defined are within ±0.5 db; however, the data response given in the following table is the data response obtainable for the tape speed defined.

TABLE II

| Tape Speed | Standard Bandwidth Data Bandwidth | S/N | Double Bandwidth Data Bandwidth | S/N |
|---|---|---|---|---|
| 60 | 100 cps - 100 kcs | 38db | 300 cps-250 kcs | 32db |
| 30 | 100 cps - 50 kcs | 38db | 300 cps-125 kcs | 32db |
| 15 | 100 cps- 25 kcs | 36db | 300 cps-62.5 kcs | 30db |
| 7.5 | 50 cps- 12.5 kcs | 36db | 300 cps-31.25 kcs | 30db |
| 3-3/4 | 50 cps- 6.25 kcs | 34db | 300 cps-15.625 kcs | 28db |
| 1-7/8 | 50 cps-3.125kcs | 34db | 300 cps-7.812 kcs | 28db |

NOTE: Some degrading of data will be caused in mixed Analog/FM or Analog/Digital systems. Adjacent channels will be reduced in signal-to-noise about 3 db.

| | |
|---|---|
| Data Input Sensitivity: | 0.5 V to 5 V rms |
| Data Input Impedance: | 100 K ohm unbalanced at 1 kc |
| Data Input Level Adjustment: | 0 - 1.8 ma of head current into a 1 mh head for standard bandwidth recordings. 1.0 ma nominal |
| Data Input Level: | 0 - 1.8 ma into a 0.5 mh head for extended bandwidth recordings. 1.0 ma nominal |
| Data Distortion: | Less than 0.3% |
| Data Frequency Response: | |
| Standard Bandwidth: | ±0.5 db from 100 cps - 100 kcs |
| Double Bandwidth: | ±0.5 db from 100 cps - 250 kcs |

| | |
|---|---|
| Bias Input Level: | 1 V rms nominal |
| Bias Input Impedance: | Greater than 2.5 K ohm |
| Bias Level Adjustment: | 0 - 16 ma into a 1 mh record head (standard bandwidth - 10 ma nominal)<br><br>0 - 10 ma adjustable into a 0.5 mh record head (double bandwidth - 8 ma nominal) |
| Bias Distortion: | Less than 0.5% |
| Reference Input Level: | 1 V rms nominal |
| Reference Input Impedance: | Greater than 8 K ohm |
| Reference Distortion: | Less than .3 of 1% |
| Bias Frequency: | Standard Bandwidth - 350 kc<br>Extended Bandwidth - 800 kc |
| Power Requirements: | +20 VDC supply: 25 ma<br>-10 VDC supply: 17 ma<br>(To delivering 8 ma rms into a 1 mh record head) |

## ANALOG BIAS OSCILLATOR (32-ABO-318-350 KC or 800 KC)

### GENERAL DESCRIPTION

A bias frequency is utilized in analog recordings to overcome the nonlinearity caused by the hysteresis of magnetic tape. In the Analog Record Amplifier, the data information and the Bias Oscillator frequency are linearly mixed. The linear mixing of these two frequencies is applied directly to the magnetic tape through the recording head. The bias frequency utilized in analog recordings is always at least three times greater than the highest data frequency. This prevents distortion of the data information by the bias frequency. The 32-ABO-813 Analog Bias Oscillator is a two-frequency oscillator. The oscillator is capable of operating at either 350 kc for standard bandwidth recordings, or 800 kc for double bandwidth recordings. The Analog Bias Oscillator may be changed from 350 kc operation to 800 kc operation by changing a soldered jumper wire on the Bias Oscillator card. A Bias Oscillator provides sufficient level to drive as many as 14 Analog Record Amplifiers simultaneously.

### PERFORMANCE SPECIFICATIONS

| | |
|---|---|
| Output Frequency (Selected): | 350 kcs or 800 kcs |
| Frequency Accuracy: | $\pm$0.5% |
| Frequency Stability: | $\pm$1% |
| Output Level Stability: | $\pm$3% |
| Output Level: | 1 V rms nominal (adjustable) R1 |
| Output Impedance: | Less than 50 ohms |
| Power Required: | +20 V<br>-10 V |

## ANALOG REFERENCE OSCILLATOR (32-ARO-xx/xx ) (11-11226-x)

## GENERAL DESCRIPTION

In magnetic tape recording, an Analog Reference Oscillator is used to record a stable reference frequency simultaneously with the recording of data information. The Reference Oscillator provides a real time reference for the data information. In playback, the reproduced Reference Oscillator frequency is used to compensate the data information. This eliminates the effects of vibration and shock which produce wow and flutter in the tape transporting mechanism. The frequency of the Reference Oscillator is usually the highest data frequency consistent with the tape speed used.

The 32-ARO Reference Frequency Oscillator is a two-speed oscillator. The two-speed oscillator works in conjunction with the High/Low speed switch on the tape transport. This oscillator has the capability of providing the two frequencies necessary for compensation consistent with the High/Low speed pair selected. For example: The 32-ARO-60/30, Analog Reference Oscillator is used with standard bandwidth recordings at tape speeds of 60 and 30 inches per second. The two frequencies of 100 kc and 50 kc represent the highest data capability for the two standard bandwidth speeds. The reference frequencies are selected consistent with the High/Low speed commands on the tape transport.

The Reference Oscillator has an output capability of mixing the reference frequency with the data in as many as 14 Analog record amplifiers, or may be recorded directly by assigning one track as a reference frequency track. Each Analog Record Amplifier has a Reference Oscillator gain control which allows the reference level of each Record Amplifier to be individually set. The Reference Oscillator is selected with frequencies consistent with the data bandwidths for the speeds used.

TABLE I

| Tape Speed in ips | Reference Oscillator Frequencies | Assembly 11-11226 |
|---|---|---|
| 60/30 | 100 kc/50 kc | -3 |
| 15/7.5 | 25 kc/12.5 kc | -2 |
| 3.75/1.875 | 6.25 kc/3.125 kc | -1 |

## PERFORMANCE SPECIFICATIONS

| | |
|---|---|
| Available Frequencies: | Consistent with Table I |
| Frequency Accuracy: | 0.1% |
| Frequency Stability: | 0.2% |
| Output Level: | 3V peak-to-peak |
| Output Impedance: | 1 K ohm |
| Oscillator Adjustments: | Output Level |
| Power Required: | +20 V Regulated<br>-10 V Regulated |

## ANALOG REPRODUCE AMPLIFIER (32-APA-801)

### GENERAL DESCRIPTION

The Analog Reproduce Amplifier accepts signals previously recorded on magnetic tape and amplifies them to a usable level. The nature of analog recordings is such that the data is recorded onto the tape in direct proportion to the input information. Thus, the Analog Reproduce Amplifier reconstructs the data precisely as it was recorded. The output impedance of the APA is low so that external equipment may reproduce the data without degradation caused by loading.

The reproduced frequency response curve from the magnetic head is not flat, because of characteristic impedance and gap losses, therefore, the reproduce amplifier must compensate for the losses. This is called equalization. The reproduce frequency response from the head is dependent upon the tape speed used to playback. Each reproduce speed is individually equalized so that the playback frequency response is flat through the data band.

The 32-APA-801, Analog Reproduce Amplifier, is designed to reproduce data signals which are in conformance with IRIG 106-60 specifications. The standard bandwidth configuration is identified by an "S" following the Leach Part Number. The double bandwidth configuration is identified by an "E" following the Leach Part Number.

The speed of tape in reproduce determines the frequency response. The Equalizers, which compensate for the reproduce head losses, are in speed pairs designed to function in conjunction with standard IRIG speed pairs.

The frequency response at each tape speed is given in the following table for both standard and double bandwidth operation. The corresponding Equalizer for the speed pairs is also given, along with the Leach Part Number.

TABLE 1

| STANDARD BANDWIDTH | | |
|---|---|---|
| Tape Speed inches/second | Leach Part Number | Bandwidth |
| 60<br>30 | 32-EQX-60/30-S | 100 cps - 100 kcs<br>100 cps - 50 kcs |
| 15<br>7.5 | 32-EQX-15/7.5-S | 100 cps - 25 kcs<br>50 cps - 12.5 kcs |
| 3.75<br>1.875 | 32-EQX-3.75/1.875-S | 50 cps - 6.25 kcs<br>50 cps - 3.125 kcs |
| **DOUBLE BANDWIDTH** | | |
| Tape Speed inches/second | Leach Part Number | Bandwidth |
| 60<br>30 | 32-EQX-60/30-E | 300 cps - 250 kcs<br>300 cps - 125 kcs |
| 15<br>7.5 | 32-EQX-15/7.5-E | 300 cps - 62.5 kcs<br>300 cps - 31.25 kcs |
| 3.75<br>1.875 | 32-EQX-3.75/1.875-E | 300 cps - 15.6 kcs<br>300 cps - 7.8 kcs |

The Equalizers for the different tape speeds are plug-in and replaceable in the Analog Reproduce Amplifier. When a different pair of speeds are desired to work in conjunction with the Tape Transport, the plug-in Equalizers are changed.

## 2. PERFORMANCE SPECIFICATIONS

The following table gives the frequency responses and signal-to-noise ratios for standard and double bandwidth operation at the standard tape speeds. All frequency response figures are flat to within ±3 db.

TABLE II

| Tape Speed inches/second | Standard Bandwidth ±3db | S/N | Extended Bandwidth ±3db | S/N |
|---|---|---|---|---|
| 60 | 100 cps - 100 kcs | 38db | 300 cps - 250 kcs | 32db |
| 30 | 100 cps - 50 kcs | 38db | 300 cps - 125 kcs | 32db |
| 15 | 100 cps - 25 kcs | 36db | 300 cps - 62.5 kcs | 30db |
| 7.5 | 100 cps - 12.5 kcs | 36db | 300 cps - 31.25 kcs | 30db |
| 3.75 | 50 cps - 6.25 kcs | 34db | 300 cps - 15.6 kcs | 28db |
| 1.875 | 50 cps - 3.12 kcs | 34db | 300 cps - 7.8 kcs | 28db |

| | |
|---|---|
| Output Level: | 5.0 V peak-to-peak continuously variable |
| Output Impedance: | 600 ohms maximum |
| Distortion (System): | 1% third harmonic at normal record level |
| Frequency Response: | Consistent with Table 1, flat to ± 3 db |
| Amplifier Adjustments: | Output Level, High Frequency Equalization |
| Equalizer Adjustments: | High Speed Mid-Frequency Level<br>Low Speed Mid-Frequency Level |
| Bias Trap: | Standard Bandwidth - Set for 350 kc<br>Extended Bandwidth - Set for 800 kc |
| Power Requirements: | +20 VDC |

## FREQUENCY MODULATION RECORD AMPLIFIER (32-FMR-802)
## GENERAL DESCRIPTION

The function of the FM Record Amplifier is to convert analog data into a frequency modulated carrier so that DC response can be obtained on magnetic tape. The FM Record Amplifier center frequency is a function of the tape speed used. The center frequency is usually in conformance with the speeds and frequencies referenced in IRIG 106-60.

The center frequency is modulated plus 40% and minus 40% for a full scale analog input. The rate of modulation, and the percent of modulation, is directly proportional to the input analog information. The level of the recorded carrier current is adequate to saturate the magnetic tape. This method of recording makes the information recorded less susceptible to the normal amplitude errors resulting from the recording process.

The 32-FMR-802, FM Record Amplifier, is designed to operate with tape speeds from 60 ips down to 1-7/8 ips. The nominal center frequency of the voltage controlled oscillator is determined by the plug-in center frequency network. One center frequency network is designed to operate at two speeds, in speed pairs, in conjunction with normal tape transport operation, as shown in Table I.

TABLE I

| Tape Speed Standard Bandwidth | Leach Part No. | High Center Frequency | Low Center Frequency |
|---|---|---|---|
| 60 and 30 ips | 32-CFN-60/30-S | 54 kc | 27 kc |
| 15 and 7.5 ips | 32-CFN-15/7.5-S | 13.5 kc | 6.75 kc |
| 3.75 and 1.875 ips | 32-CFN-3.75/1.875-S | 3.375 kc | 1.688 kc |
| **Tape Speed Double Bandwidth** | **Leach Part No.** | **High Center Frequency** | **Low Center Frequency** |
| 60 and 30 ips | 32-CFN-60/30-E | 108 kc | 54 kc |
| 15 and 7.5 ips | 32-CFN-15/7.5-E | 27 kc | 13.5 kc |
| 3.75 and 1.875 ips | 32-CFN-3.75/1.875-E | 6.75 kc | 3.375 kc |

The center frequencies can be selected by the insertion of the correct center frequency network. For example: The 32-CFN-60/30-S, Center Frequency Network establishes the center carrier frequency for 60 and 30 ips operation. These standard frequencies are 54 kcs and 27 kcs. The 32-CFN-60/30-E, Center Frequency Network, establishes the center carrier frequency for 60 and 30 ips double bandwidth operation. The double bandwidth frequencies are 108 kcs and 54 kcs.

The data response is dependent on the carrier frequency and tape speed. The data response, in all cases, starts from DC and extends to the frequencies tabulated in Table II.

TABLE II

| Carrier Frequency | Maximum Data Response |
|---|---|
| 108 kcs | 20 kcs |
| 54 kcs | 10 kcs |
| 27 kcs | 5 kcs |
| 13.5 kcs | 2.5 kcs |
| 6.75 kcs | 1.25 kcs |
| 3.375 kcs | .625 kcs |
| 1.668 kcs | .312 kcs |

## PERFORMANCE SPECIFICATIONS

Table III presents available frequency responses and signal-to-noise ratios for the standard tape speeds and center frequencies. All bandwidths are flat to within ±0.5 db.

TABLE III

| Tape Speed, ips | Standard Bandwidth | | | Extended Bandwidth | | |
|---|---|---|---|---|---|---|
| | Carrier | Bandwidth | S/N | Carrier | Bandwidth | S/N |
| 60 | 54 kc | DC-10 kc | 42db | 108 kc | DC-20 kc | 42db |
| 30 | 27 kc | DC-5 kc | 42db | 54 kc | DC-10 kc | 42db |
| 15 | 13.5 kc | DC-2.5 kc | 40db | 27 kc | DC-5 kc | 40db |
| 7.5 | 6.75 kc | DC-1.25 kc | 40db | 13.5 kc | DC-2.5 kc | 40db |
| 3.75 | 3.375 kc | DC-.625 kc | 38db | 6.75 kc | DC-1.25 kc | 38db |
| 1.875 | 1.688 kc | DC-.312 kc | 38db | 3.375 kc | DC-.625kc | 38db |

| | |
|---|---|
| Input Sensitivity: | ±250 mv p/p to ± 2.5 V p/p continuously variable |
| DC Offset: | Adjustable from 0 to -5 V |
| Input Impedance: | 100 K ohm minimum |
| Stability: | 0.5% long term |
| Linearity: | 1.0% of best straight line |
| Amplifier Center Frequencies: | 1.688 kcs to 108 kcs in speed pairs of: 60/30; 15/7.5; and 3.75/1.875. |
| Amplifier Adjustments: | Input Sensitivity, Center Frequency (DC Offset) |
| Power Required: | +20, +10 and -10 volts regulated |

## FM REPRODUCE AMPLIFIER (32-FMP-803)
## GENERAL DESCRIPTION

The FM Reproduce Amplifier translates the FM recording (modulated carrier) back to the original data signal through the use of a frequency discriminator. The discriminator is characterized by a linear relationship between input frequency and output voltage over a certer frequency deviation of $\pm$40%. The center frequency is dependent upon the tape speed used. The center frequency can be selected in the 32-FMP-803 to be in accordance with the standard bandwidth recordings, or in accordance with double bandwidth recordings.

The FM Reproduce Amplifier is a two-speed reproduce amplifier. The two speeds are in accordance with the two-speeds available on the Tape Transport. Speeds are in speed pairs, three of which give the six standard tape speeds. The 32-FMP-803 is equipped with a plug-in, Low Pass Filter. The plug-in Low Pass Filter is in accordance with the data bandwidths and center frequencies associated with the Tape Transport speeds.

The data response in reproduce is dependent upon the carrier frequency and tape speed. The data response in all cases starts from DC and extends to the frequencies tabulated in Table I. The associated carrier frequency is given with the maximum data response.

TABLE I

| Carrier Frequency | Maximum Data Response |
|---|---|
| 108 kc | 20 kc |
| 54 kc | 10 kc |
| 27 kc | 5 kc |
| 13.5 kc | 2.5 kc |
| 6.75 kc | 1.25 kc |
| 3.375 kc | .625 kc |
| 1.668 kc | .312 kc |

The 32-FMP-803 Reproduce Amplifier is designed to operate with tape speeds of 60 ips, down to 1-7/8 ips.

For example: The 32-FIL-60/30-S, Low Pass Filter, establishes the center frequency and data response for 60 and 30 ips operation. The standard carrier frequencies are 54 kc and 27 kc. The 32-FIL-60/30-E Low Pass Filter establishes the center carrier frequencies and data responses for 60 and 30 ips double bandwidth operation. The double bandwidth frequencies are 108 kc and 54 kc.

When a Los Pass Filter has been selected, the center frequency and data response of operation is commanded by the speed selection switch input. For example: With a 60 and 30 ips operation, and the 32-FIL-60/30-S, Low Pass Filter Network used, when the switch is put in the high speed (60 ips), the 54 kc center frequency and a data response of 10 kc is obtained. When the switch is placed in the low speed (30 ips), the 27 kc center frequency and a 5 kc data response is obtained.

## PERFORMANCE SPECIFICATIONS

Table II gives available frequency responses and signal-to-noise ratios in recording and reproduction for the standard tape speeds and center frequencies. All bandwidths are flat to within ±0.5 db for recording and reproducing.

TABLE II

| Tape Speed in ips | Standard Bandwidth | | S/N | Extended Bandwidth | | S/N |
|---|---|---|---|---|---|---|
| | Carrier | Data Bandwidth | | Carrier | Data Bandwidth | |
| 60 | 54 kc | DC- 10 kc | 42db | 108 kc | DC- 20 kc | 42db |
| 30 | 27 kc | DC- 5 kc | 42db | 54 kc | DC- 10 kc | 42db |
| 15 | 13.5 kc | DC- 2.5 kc | 40db | 27 kc | DC- 5 kc | 40db |
| 7.5 | 6.75 kc | DC- 1.25 kc | 40db | 13.5 kc | DC- 2.5 kc | 40db |
| 3.75 | 3.375 kc | DC- .625 kc | 38db | 6.75 kc | DC- 1.25 kc | 38db |
| 1.875 | 1.688 kc | DC- .312 kc | 38db | 3.375 kc | DC- .625 kc | 38db |

Output Level: 5 V p/p continuously variable
Output Impedance: 1.25 K ohm maximum
Linearity: 0.5% of best straight line
Stability; 0.5% long term under environment
Amplifier Adjustments: DC Offset and Output Level
Discriminator Center Frequency: 1.688 kc to 108 kc in speed pairs of 60/30, 15/7.5, and 3.75/1.875.

Power Required: +20, +10 and -10 volts regulated
-13 volts unregulated

## UNIVERSAL DIGITAL RECORD AMPLIFIER (32-DRA-804)

## GENERAL DESCRIPTION

The Universal Digital Record Amplifier is designed to accept recording formats in the NRZ Change or NRZ Mark format. This Record Amplifier also accepts an NRZ digital clock which it synchronizes to the input data.

The Universal Digital Record Amplifier is designed to operate in three modes. The operation of the Digital Record Amplifier is dictated by the inter-wiring of the terminals available on the Record Amplifier board. The three basic modes of operation are:

1. NRZ Change or NRZ Mark data recorded synchronous with clock.

2. The transformation of NRZ Change data to an NRZ Mark recording format.

3. The recording of an NRZ Clock.

In the first recording format, information supplied to the Digital Record Amplifier, whether it is NRZ Change or NRZ Mark information, is clocked onto the tape in synchronism with the input data clock. The information recorded onto the tape is delayed in real time one-half of a data bit width in order to perform the synchronization process.

The second type of recording format, which transforms NRZ Change information to NRZ Mark information, inspects the NRZ Change input and synchronizes all data "1's" in the format into a transition consistent with the NRZ Mark technique. In this recording process, all data "0's" in the NRZ Change input data result in no transition recorded on the tape.

The third type of recording process is with no data input and only NRZ Clock information available at the input of the Universal Record Amplifier. In this configuration, a transition is recorded onto the tape for every negative excursion of the input data clock. This results in NRZ Mark recording of the clock information, recording one transition for every data bit period. The Universal Digital Record Amplifier in all types of recording synchronizes the digital data input with the digital clock input. Corrections can be made with this Record Amplifier in the time base parallelism of parallel input data bits for as much as one-half bit period error. Since the clock synchronizes the input data at a point precisely at the middle of the data bit period, time parallel skew can be corrected in the recording process by the Universal Digital Record Amplifier.

## PERFORMANCE SPECIFICATIONS

| | |
|---|---|
| Data Input Level: | |
| False State: | 0 V $\pm$ 1 VDC |
| True State: | 6 - 12 VDC |
| Input Impedance: | 100 K ohm or greater |

| | |
|---|---|
| Clock Input Level: | |
| False State: | 0 V |
| True State: | 6 - 12 VDC |
| Clock Rate: | Twice data rate |
| Clock Synchronism: | Positive clock excursion for start of bit period time |
| Clock Input Impedance: | 100 K ohm or greater |
| Data Input Format: | NRZM or NRZC |
| Output Level: | Sufficient to drive a 1 mh record head for the saturation recording of magnetic tape |
| Maximum Data Input Rate: | 150 K bits/sec, per channel |
| Maximum Clock Input Rate: | 150 K bits/sec, per channel |
| Monitor Points: | TP-1, Head Current Monitor |
| Power Required: | +2-, +10 and -10 volts regulated |

## DIGITAL CLOCK PLAYBACK AMPLIFIER (32-CPA-821)

## GENERAL DESCRIPTION

In a Digital Reproduce System, the Clock Playback Amplifier functions to reproduce the recorded NRZ Mark clock signal, generates an NRZ Clock output and provides trigger pulses, time coincident with the center of the bit cell, which reads out the stored data of the Digital Data Playback Amplifiers.

Figure DCPA-1 is a block diagram of the multitrack reproduce system. Since the clock is recorded in an NRZ Mark format, there is one flux change per data character on the clock track. The clock is reconstructed by using this flux change to trigger a delay multivibrator that has a 50% duty cycle at the specific bit rate.

## PERFORMANCE SPECIFICATIONS

| | |
|---|---|
| Output Level: | |
| True State: | 6 v $\pm$0.5 v |
| False State: | 0 v $\pm$0.5 v |
| Output Rise and Fall Time: | 0.3 microseconds maximum |
| Output Impedance: | |
| True Level: | 600 ohms maximum |
| False Level: | 19 ma of reverse sync current |
| Output Format: | NRZ (Square Wave at twice data rate) |
| Output Data Rate: | 2.25 K Bits/second at 1 7/8 ips<br>4.5 K Bits/second at 3 3/4 ips<br>7.5 K Bits/second at 7 1/2 ips<br>15.0 K Bits/second at 15 ips<br>24 K Bits/second at 30 ips<br>48 K Bits/second at 60 ips |
| Power Required: | +20, +10 and -10 volts regulated |

## DIGITAL REPRODUCE AMPLIFIER AND SKEW CORRECTION (32-DPA-806C)

## GENERAL DESCRIPTION

The purpose of the Digital Reproduce System is to transform a multi-track NRA Mark recording into a six volt NRZ change or NRZ Mark output for each data track. The NRZ Mark Clock recording is also reproduced and transformed into an NRZ change or NRZ mark output that is time coincident with each output data character.

Figure DPAN-1 is a block diagram of the reproduce system. Since the clock is recorded in an NRZ Mark format, there is one flux change per data character on the clock track. The clock is reconstructed by using this flux change to trigger a one-shot multivibrator that has a 50% duty cycle at the specific bit rate, which in turn is dependent on the tape speed.

Time displacement errors due to small but finite skew of the tape as it passes over the record and then, subsequently over the reproduce head stacks, as well as static skew due to the mechanical tolerances of the heads themselves are eliminated by gating the outputs of the data tracks with the clock signal.

## PERFORMANCE SPECIFICATIONS

| | |
|---|---|
| Output Level: | |
| True State: | 6 v $\pm$0.5 v |
| False State: | 0 v $\pm$0.5 v |
| Output Rise and Fall Time: | 0.3 microseconds maximum |
| Output Impedance: | |
| True Level: | 600 ohms maximum |
| False Level: | 19 ma of reverse sync current |
| Output Format: | NRZ Change or NRZ Mark (Skew Corrected) |
| Output Data Rate: | 2.25 K Bits/sec at 1 7/8 ips<br>4.5 K Bits/sec at 3 3/4 ips<br>7.5 K Bits/sec at 7 1/2 ips<br>15.0 K Bits/sec at 15 ips<br>24.0 K Bits/sec at 30 ips<br>48.0 K Bits/sec at 60 ips |
| Power Required: | +20, +10 and -10 VDC |

LEACH CORPORATION

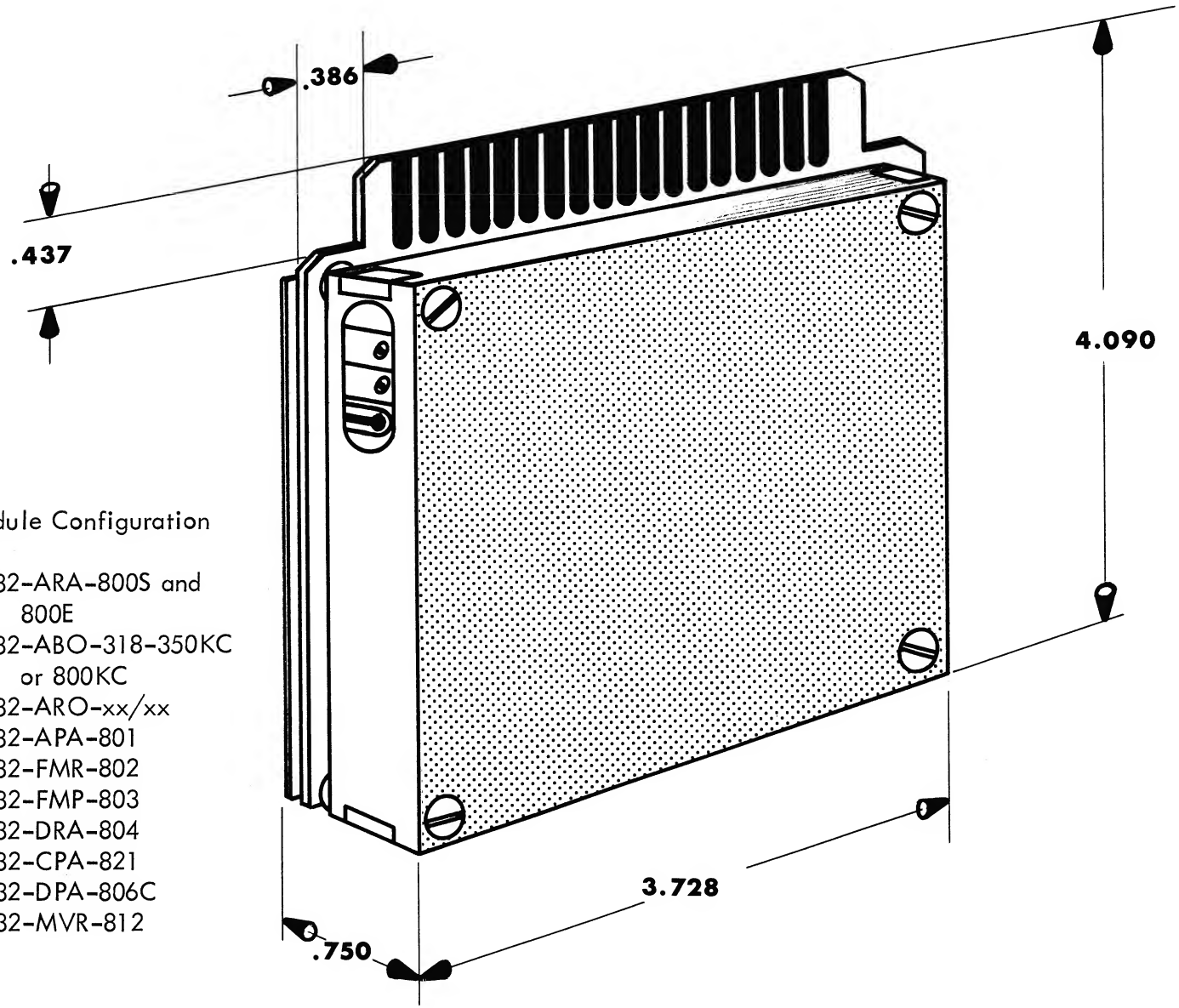
## MULTIPLE VOLTAGE REGULATOR (32-MVR-812)

## GENERAL DESCRIPTION

The Multiple Voltage Regulator (MVR) provides DC to DC isolation through transformer coupling and provides the proper voltage levels to power the signal conditioning electronics in the MTR-3200 System. The MVR operates from the 19.5 V ±0.5 V supplied by the System Pre-Regulator. The MVR creates three regulated voltages and one unregulated voltage. The four voltage levels are adequate to drive any of the signal conditioning electronics, or oscillators, with Model Number prefixed 32.

## PERFORMANCE SPECIFICATIONS

| | |
|---|---|
| Input Voltage | 19.5 V ± 0.5 V |
| Regulated Output Voltages: | +20 VDC<br>+10 VDC<br>-10 VDC |
| Unregulated Output Voltage: | -13 VDC |
| Accuracy of Regulated Supplies: | 0.25% under all conditions of load and input line variation |
| Maximum Output Power: | 14 watts total |
| Maximum Load for each Supply: | |
| +20 V: | 600 ma |
| +10 V: | 750 ma |
| -10 V: | 750 ma<br>(The combination of power drain cannot exceed 14 watts total) |
| Stability of unregulated -13 V: | ±20% |
| Voltage Regulator Adjustment: | +20 V Level<br>+10 V Level<br>-10 V Level |
| Maximum Ripple of each of the 3 Regulated Supplies: | 10 mv peak-to-peak |




Module Configuration for:

- 32-ARA-800S and 800E
- 32-ABO-318-350KC or 800KC
- 32-ARO-xx/xx
- 32-APA-801
- 32-FMR-802
- 32-FMP-803
- 32-DRA-804
- 32-CPA-821
- 32-DPA-806C
- 32-MVR-812

## SYSTEM PRE-REGULATOR (32-SPR-809)

## GENERAL DESCRIPTION

The function of the 32-SPR-809 System Pre-Regulator is to accept 24-32 VDC input power and provide a regulated 19.5 VDC $\pm$ 0.5 VDC. The 19.5 VDC output supplies power to the 400/200 cps Inverter and to the electronics Multiple Voltage Regulators. The Pre-Regulator is a constant power device. It is a duty cycle regulator because as the input system voltage goes up, the pulse width of the output regulated portion of the supply goes down. This approach to system input regulation achieves maximum efficiency while maintaining good regulation output characteristics.

## PERFORMANCE SPECIFICATIONS

| | |
|---|---|
| Input Voltage: | 24-32 VDC |
| Output Voltage: | 19.5 VDC $\pm$ 0.5 VDC |
| Output Current: | 3 amps continuous -<br>5 amps surge capacity |
| Output Regulation: | 1% from 25% to 100% of full load capacity |
| Protection: | Automatic short circuit protection internal to the System Pre-Regulator |

## MOTOR INVERTER (32-INV-810-400/200)

## GENERAL DESCRIPTION

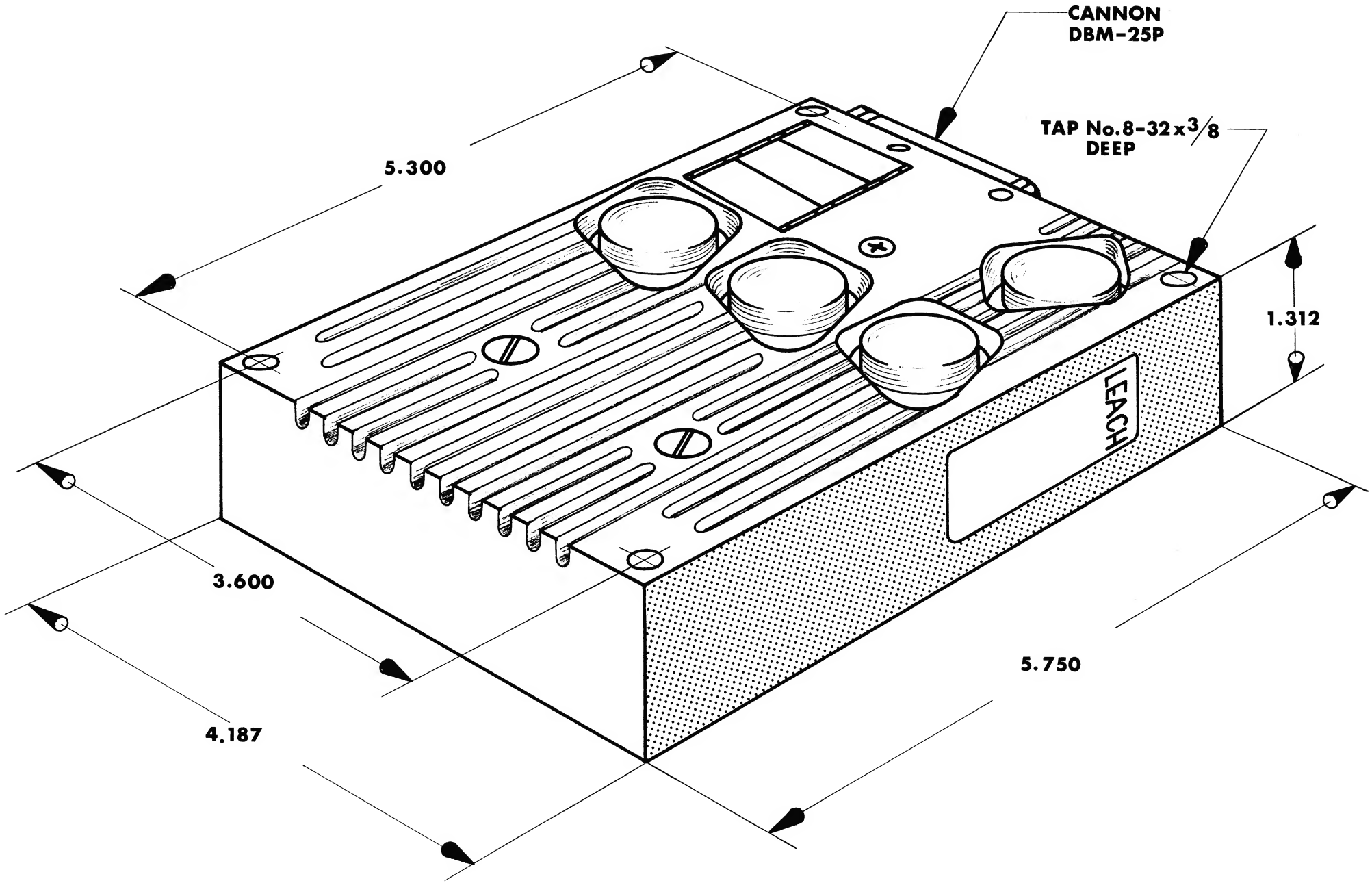
The Motor Drive Inverter (32-INV-810) accepts the DC input from the output of the System Pre-Regulator at 19.5 V $\pm$ 0.5 V, and from this DC voltage generates a precision 400 cps or 200 cps AC voltage sufficient to drive the capstan motor and the reel drive motor.

In the high speed mode of operation, the Motor Drive Inverter delivers 400 cps at 40 V rms. This 40 V rms is delivered to both the capstan and reel drive motors. In the low speed mode of operation, the Motor Drive Inverter produces 200 cps at approximately 23 V rms to drive the capstan drive and reel drive motors. The AC output of the Inverter is two-phase. The two-phase output eliminates the inefficiencies usually associated with a phasing capacitor in driving a hysteresis synchronous motor.

## PERFORMANCE SPECIFICATIONS

The 32-INV-810-400/200 Motor Inverter is designed specifically to drive the hysteresis synchronous motors in the MTR-3200 transport. The following specifications are applicable:

| | |
|---|---|
| Input Voltage: | 19.5 V $\pm$ 0.5 V |
| Output Voltage: | 400 cps - 40 V rms<br>200 cps - 23 V rms |
| Output Phasing: | 2-phase -90° $\pm$ 3° |
| Output Frequency Accuracy: | $\pm$0.25% |
| Output Power: | 45 watts peak, each phase<br>25 watts nominal, each phase |
| Efficiency: | Under nominal load conditions -<br>25 watts per phase, approximately 85% |
| Control of Frequency Output: | HI/LO speed switch on the tape transport controls 400 or 200 cps output |




MOTOR INVERTER

32-INV-810

666-23

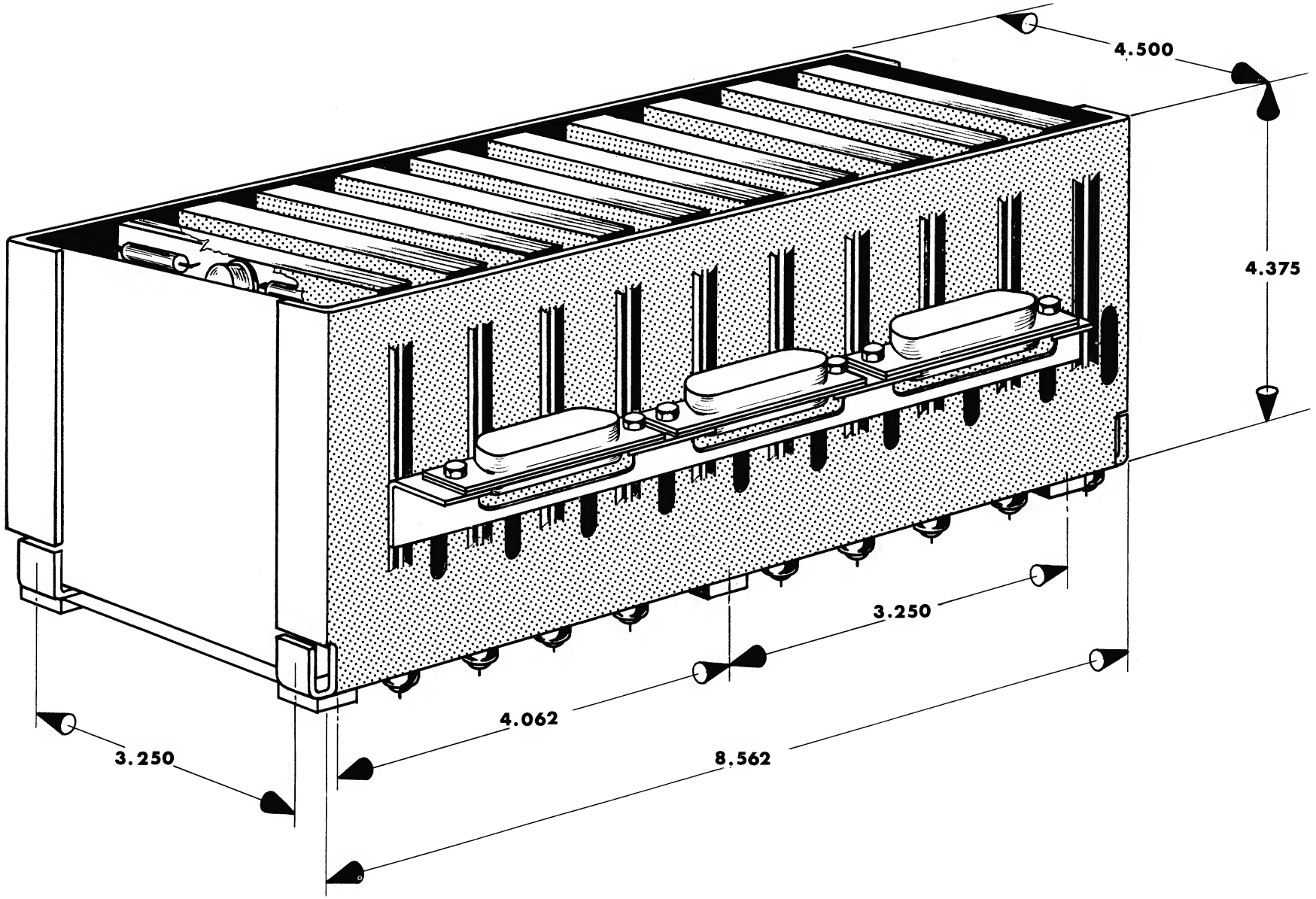
## ELECTRONIC MODULE HOUSING ASSEMBLY (32-EMH-811)

### GENERAL DESCRIPTION

The Electronic Module Housing Assembly is designed to accept data electronics cards, provide electrical power and input/output connections. The housing will hold any module with type number prefixed 32 except the Motor Inverter (32-INV-810) and Pre-Regulator (32-SPR-809).

### PERFORMANCE SPECIFICATIONS

| | |
|---|---|
| Input Power | 19.5 $\pm$0.5 V DC |
| Capacity: | 10 modules |




MODULE HOUSING

32-EMH-811

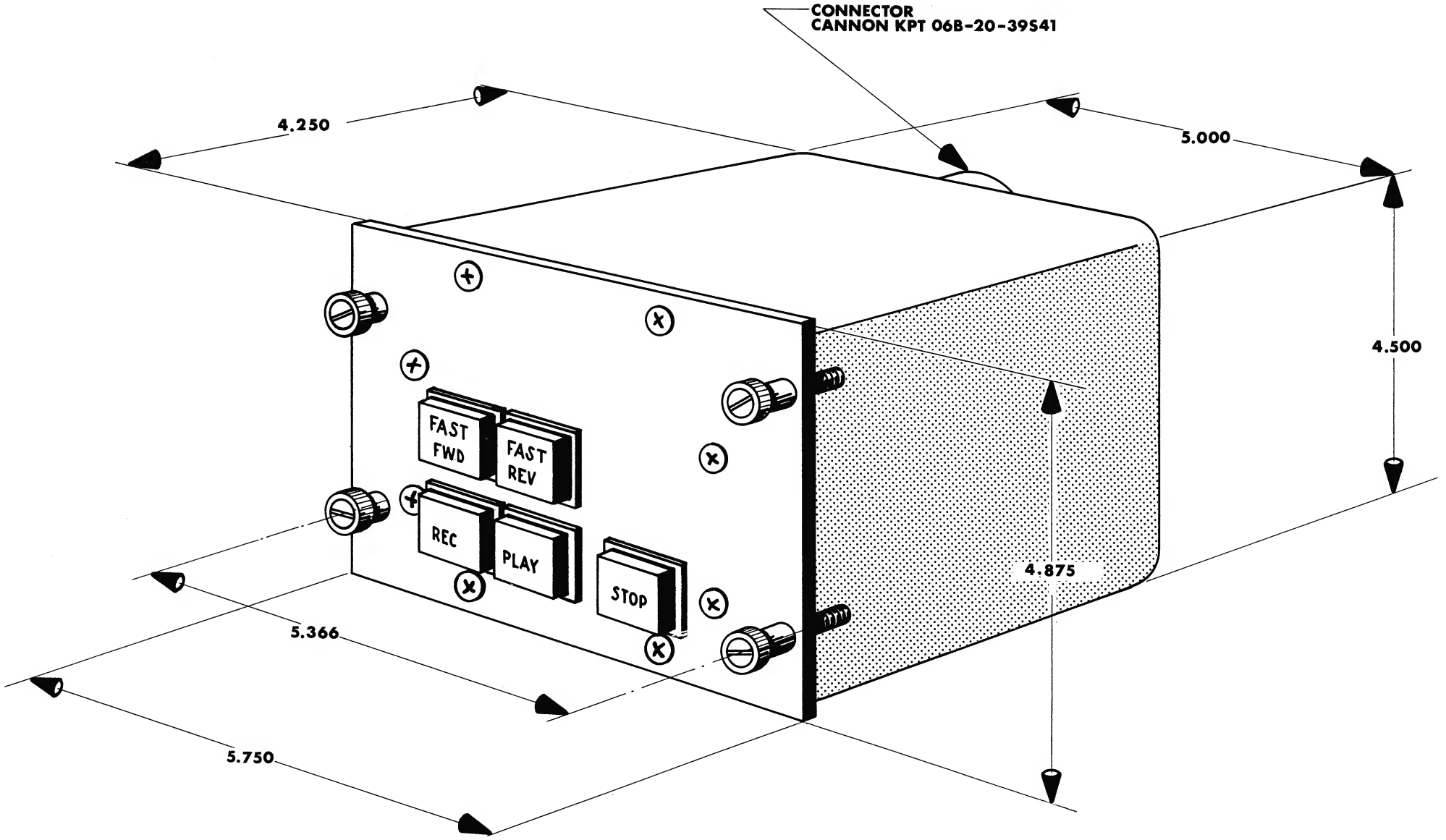
## REMOTE CONTROL (32-RCU-814)

## GENERAL DESCRIPTION

The Remote Control contains the function switches to place the MTR-3200 Record/ Reproduce System into a selected operating mode, when connected to the remote control connector on the transport. The switches are in parallel with the local control switches on the transport, so that commands can be given at both locations.

## PERFORMANCE SPECIFICATIONS

| | |
|---|---|
| Control Switches: | Backlighted momentary contact |
| Functions: | Record - Playback - Stop<br>Fast Forward - Fast Rewind |
| Cable Length :<br>(Cable not furnished) | Up to 100 feet |
| Power: | Furnished through cable from MTR-3200 |




REMOTE CONTROL

32-RCU-814

666-28

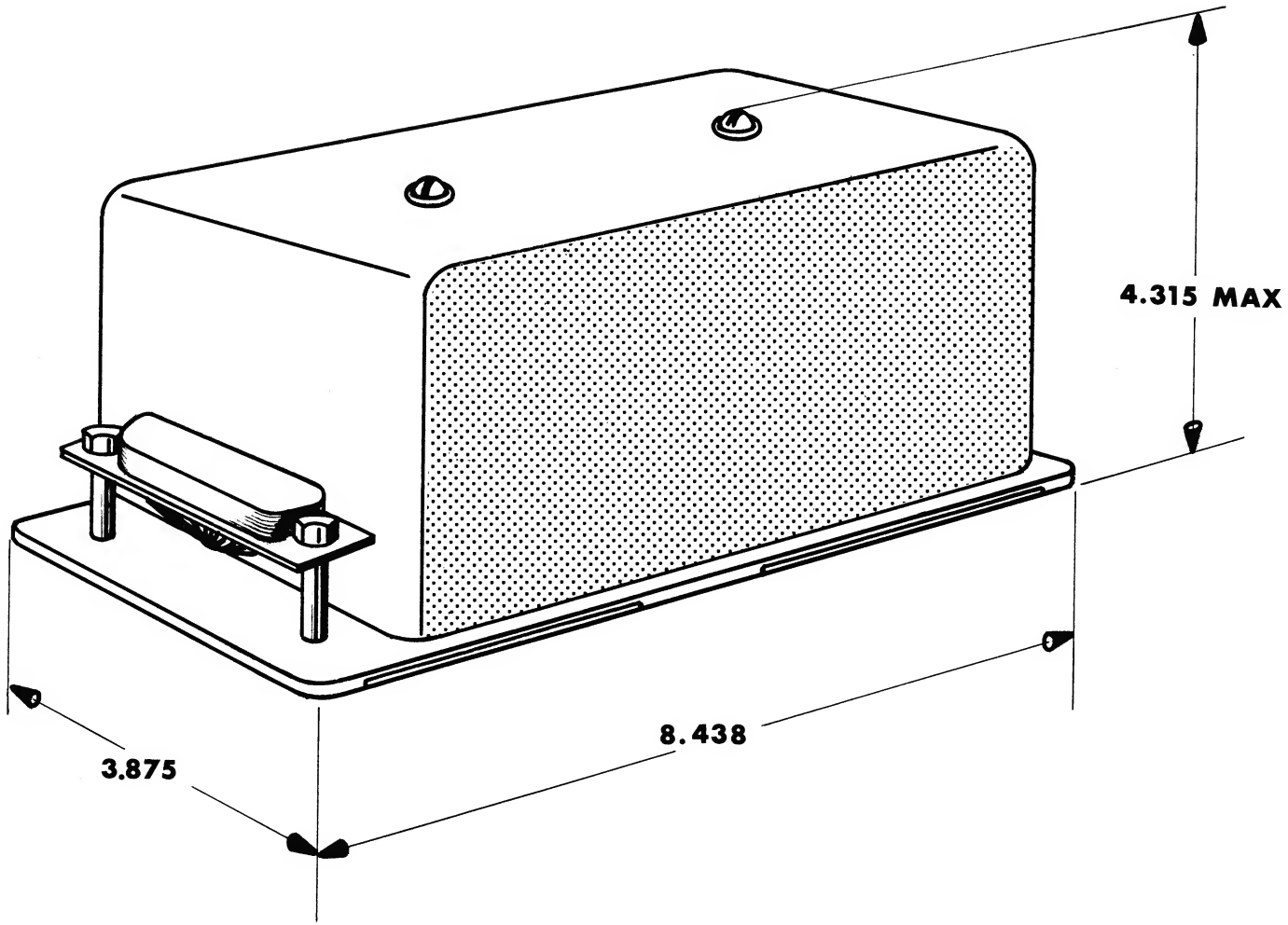
## POWER CONVERTER (32-1VC-850)

### GENERAL DESCRIPTION

The power converter accepts line AC power and produces nominal 28V DC to operate the MTR-3200 Recorder/Reproducer System.

### PERFORMANCE SPECIFICATIONS

| | |
|---|---|
| Input Voltage: | 115 volts ±10 volts |
| Input Frequency: | 60 cps ±5%, single phase |
| Output Voltage | 28 volts DC at 115 volt input.<br>25 to 31 volts DC when the input is varied ±10% |
| Output Power: | 150 watts maximum |
| Regulation: | Within voltage specification over a load range from 3 to 150 watts |
| Ripple: | 100 mv p-p at 3 amperes load |
| Surge | 20 amperes for 10 ms with output voltage 24 V DC minimum |
| Output Adjustment: | An output voltage level adjustment is available inside the power supply |




POWER CONVERTER

32-IVC-850

## MAGNETIC TAPE

The following table lists magnetic tape products manufactured by 3M Company, Magnetic Products Division. This tape may be purchased directly from the 3M Company by the Catalog Numbers shown.

### MAGNETIC TAPE

| CATALOG NUMBER | REEL DIAM. | REELS PER CTN. | APPROX. WT. PER CTN. | PRICE PER ROLL IN QUANTITIES INDICATED | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | 1-99 | 100-249 | 250-499 | 500-999 | 1000+ |
| 100 KC RECORDER | | | | | | | | |
| *599-1/2-1800-R50 | 8" | 10 | | $30.99 | $30.38 | $29.78 | $29.20 | $28.63 |
| *599-1-1800-R50 | 8" | 5 | | 46.79 | 45.87 | 44.97 | 44.09 | 43.23 |
| 250 KC RECORDER | | | | | | | | |
| *951-1/2-2300-R50 | 8" | 10 | | 39.44 | 38.67 | 37.91 | 37.17 | 36.44 |
| *951-1-2300-R50 | 8" | 5 | | 63.70 | 62.45 | 61.23 | 60.03 | 58.85 |
| DIGITAL RECORDER | | | | | | | | |
| **8938F-1/2-1200-R55C40-Z | 8" | 10 | 31 | 17.09 | 16.45 | 16.14 | 15.82 | 15.50 |

### ACCESSORIES

| | | | 1-9 | 10-49 | 50+ |
|---|---|---|---|---|---|
| EMPTY REEL IN BOX | | | | | |
| *1/2-R50-8 | 8" | 10 | $17.21 | $16.35 | $15.49 |
| *1-R50-8 | 8" | 5 | 18.04 | 17.13 | 16.25 |
| EMPTY DIGITAL REEL AND CONTAINER | | | | | |
| **1/2-R55-8-C40 | 8" | 10 | 11.73 | 11.14 | 10.56 |

PACKAGING * EACH REEL OF TAPE IS INDIVIDUALLY SEALED IN A PLASTIC BAG AND IS INDIVIDUALLY BOXED.

** EACH REEL IS INDIVIDUALLY PACKED IN A ROUND PLASTIC CONTAINER.

LEACH CORPORATION

## LEACH MODEL AR-130
## ANALOG RECORD AMPLIFIER

The AR-130 Analog Record Amplifier is a silicon solid state three input device which includes the circuitry for amplification of analog or multiplex RDB FM/FM data signals, timing or reference data, and bias signal. The bias amplifier is a tuned push-pull power amplifier for low distortion amplification of 350 KC bias. The outputs from the analog, reference and bias amplifiers are linear mixed and used to drive the 1 mh tape record heads.

### ELECTRICAL SPECIFICATIONS:

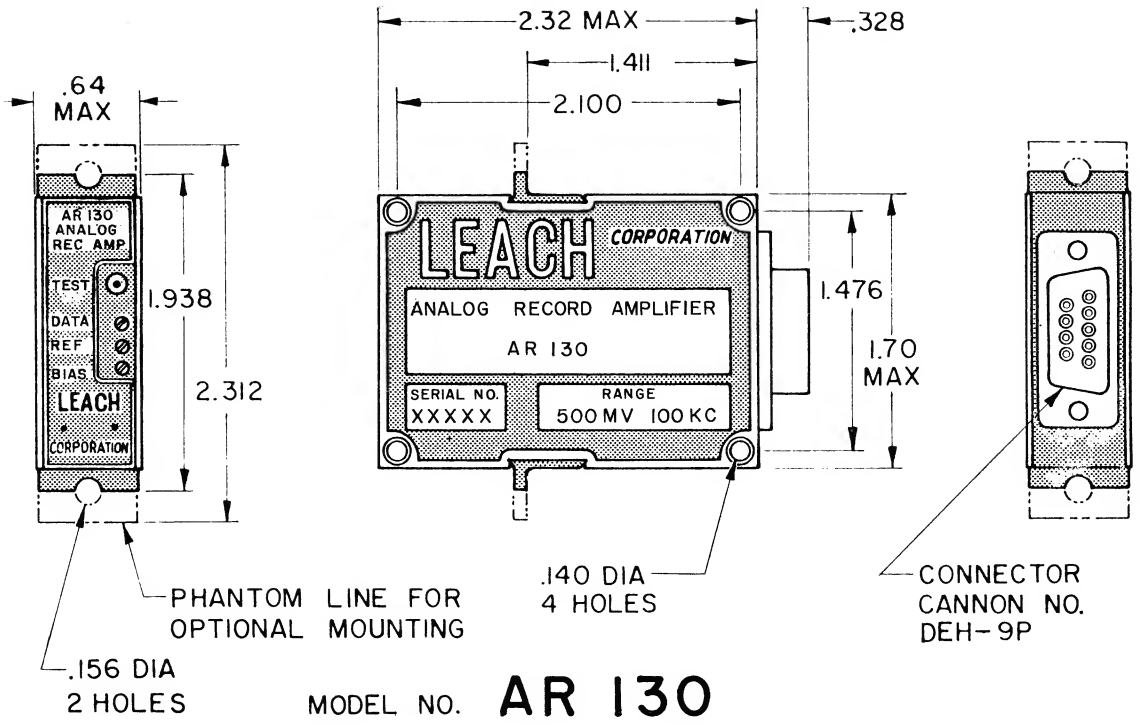
| | |
|---|---|
| Data Input Impedance: | Greater than 100 K ohm unbalanced to ground shunted with 15 uufd. |
| Data Input Sensitivity: | 0.5 Volts to 1.5 Volts rms. |
| Data Maximum Record Current: | 2 ma rms. |
| Data Harmonic Distortion | 1% maximum |
| Data Frequency Response: | 50 cycles to 100 KC ± 1 db. |
| Reference Input Impedance: | 100K minimum shunted with 15 uufd. |
| Reference Maximum Record Current: | 2 ma rms. |
| Reference Frequency Response: | ± 1 db 1,000 cycles to 100 kc. |
| Reference Harmonic Distortion: | 1% maximum. |
| Bias Operating Frequency: | 350 kc ± 1% |
| Bias Input Impedance: | 5,000 ohms minimum |
| Bias Input Level: | 1.5 volt rms nominal |
| Bias Output: | 18 ma rms into 1 mh direct record head with resonant frequency above 500 kc. |
| Noise Level: | 40 db below normal record level. |
| Controls: | Separate gain adjust for data input, reference input and bias input for setting proper record current. |
| Test Point: | For output voltage monitor |
| Total Unit Power and Voltage: | 20 volts DC at 65 ma. |

### ENVIRONMENTAL SPECIFICATIONS:

| | |
|---|---|
| Temperature: | -40°F to +185°F |
| Shock: | 500 G Peak |
| Acceleration: | 200 G |
| Vibration: | 20 G to 10 to 2,000 cps |
| Humidity: | 0 to 95% relative humidity |

### MECHANICAL SPECIFICATIONS:

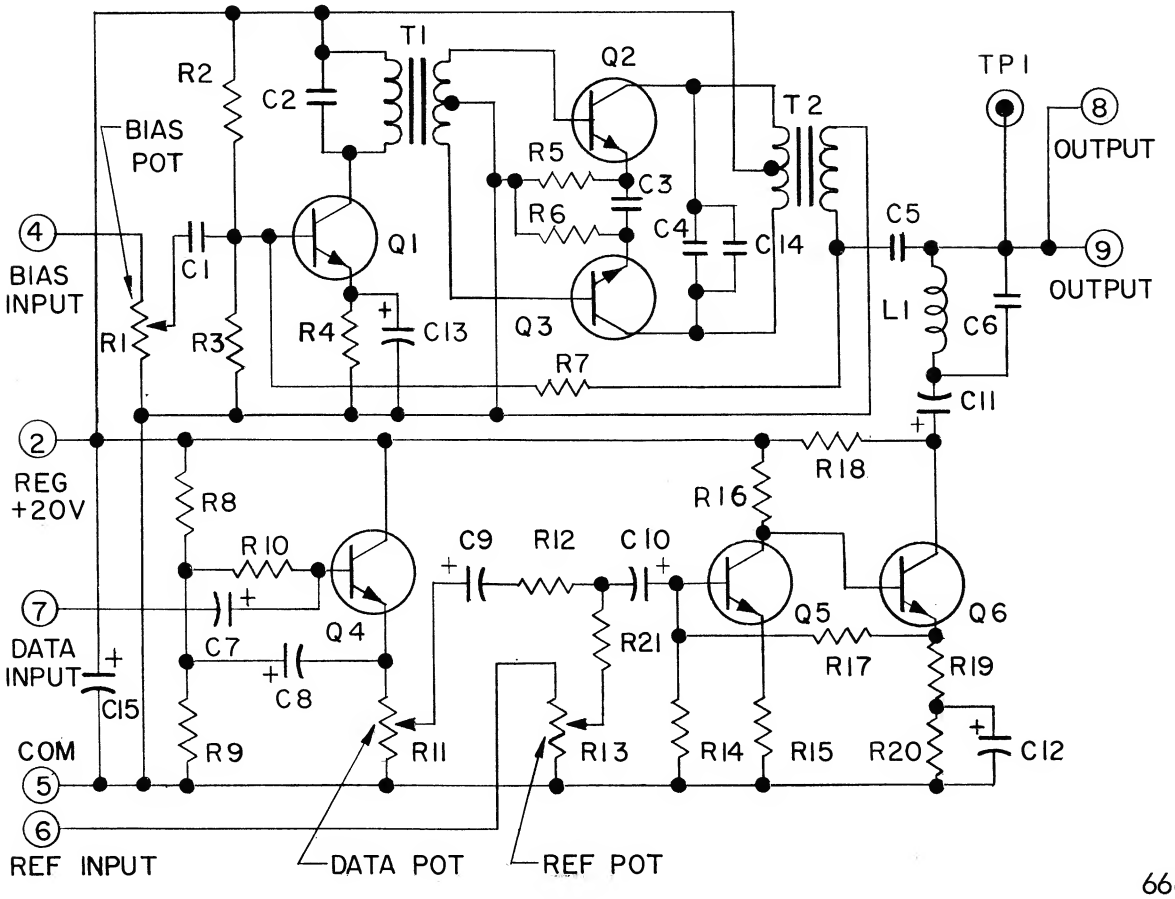
| | |
|---|---|
| Size: | 2,640" by 1.67" by 0.625" including connector. |
| Weight: | 3.0 ounces |
| Electrical Connector: | DEH-9P |
| Part Numbering System: | Basic Number AR-130 |




MODEL NO. **AR 130**

MATING CONNECTOR (NOT FURNISHED)
CANNON DE-9S

ALL DIMENSIONS NOMINAL UNLESS
OTHERWISE SPECIFIED



LEACH CORPORATION

## LEACH MODEL RO-330-350
## BIAS OSCILLATOR

These bias oscillators utilize solid state silicon design to achieve minimum size and good performance under severe environmental conditions. The output is suitable for use with up to 14 of the Leach Direct Recording Amplifiers, Model AR-130.

### ELECTRICAL SPECIFICATIONS:

| | |
|---|---|
| Frequency: | 350 KC for use with the AR-130 |
| Frequency Stability: | ± 1% |
| Output Voltage: | 2.5 volts rms minimum. |
| Output Impedance: | Less than 500 ohms. |
| Power Requirements: | 20 volts DC at 15 ma. |
| Test Point: | For frequency monitor. |

### ENVIRONMENTAL SPECIFICATIONS:

| | |
|---|---|
| Temperature: | -40°F to +185°F |
| Shock: | 500 G peak |
| Acceleration: | 200 G |
| Vibration: | 20 G, 10 to 2,000 cps |
| Humidity: | 0 to 95% RH |

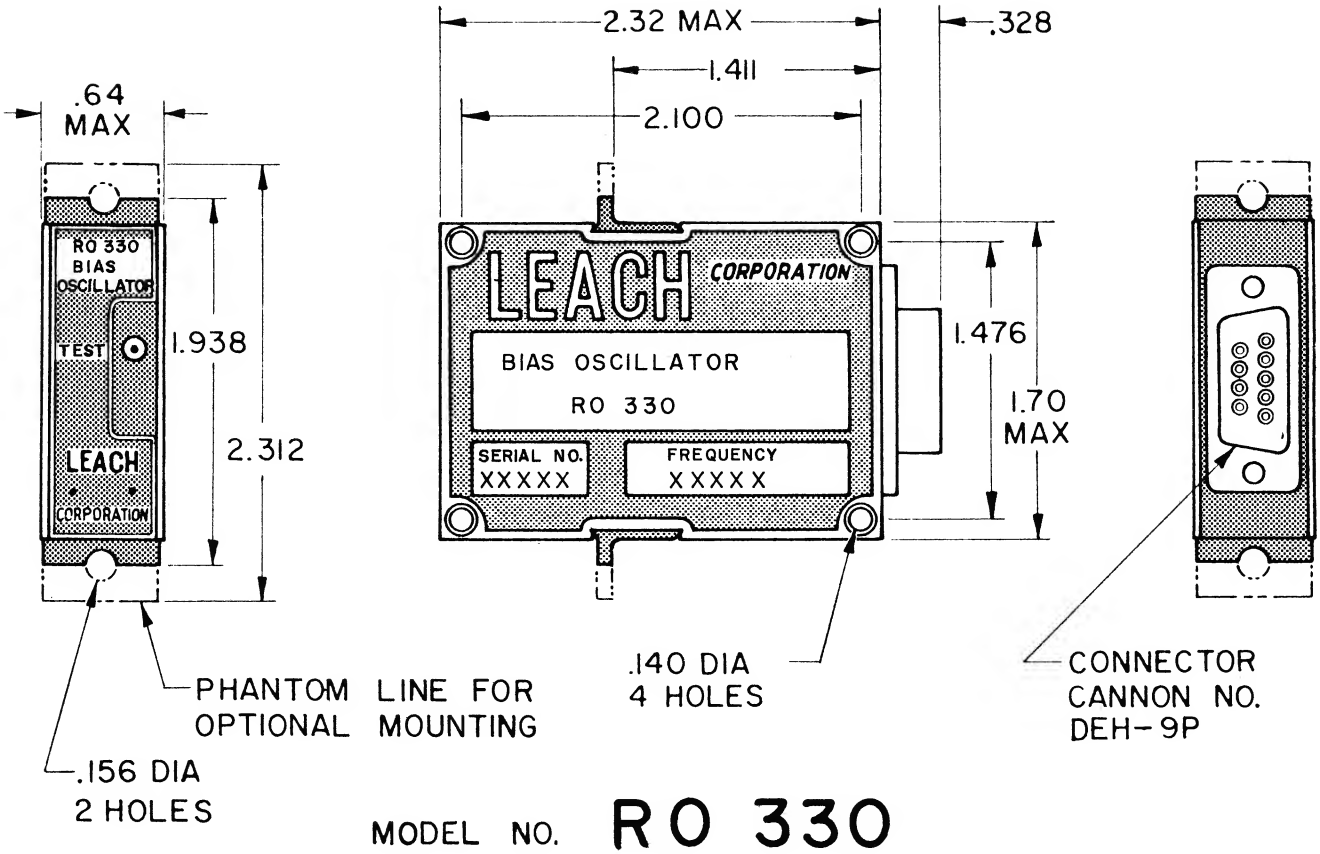
### MECHANICAL SPECIFICATIONS:

| | |
|---|---|
| Size: | 2.640" by 1.67" by 0.625" including connector |
| Weight: | 2.75 ounces |
| Electrical Connector: | DEH-9P |

Part Numbering System:

| Basic Number | | Frequency kc |
|---|---|---|
| RO-330 | - | 350 (kc osc.) |

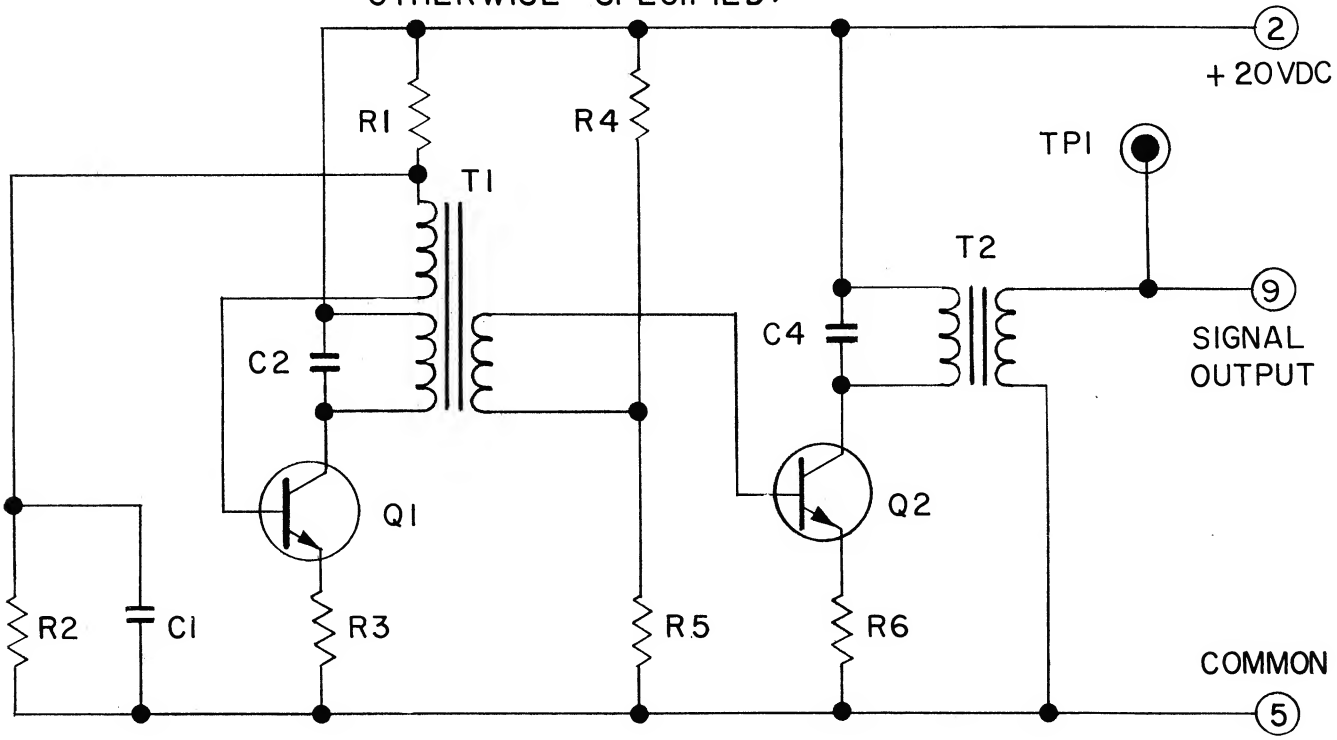
LEACH CORPORATION




MODEL NO. **RO 330**

MATING CONNECTOR (NOT FURNISHED)
CANNON DE-9S.

ALL DIMENSIONS NOMINAL UNLESS
OTHERWISE SPECIFIED.




666-35

LEACH CORPORATION

## LEACH MODEL RO-320
## REFERENCE OSCILLATOR

This is a highly stable LC reference oscillator, available at set frequencies over a frequency range from 1 kc to 100 kc. It utilizes solid state silicon design to achieve minimum size and maximum performance under severe environmental conditions.

### ELECTRICAL SPECIFICATIONS:

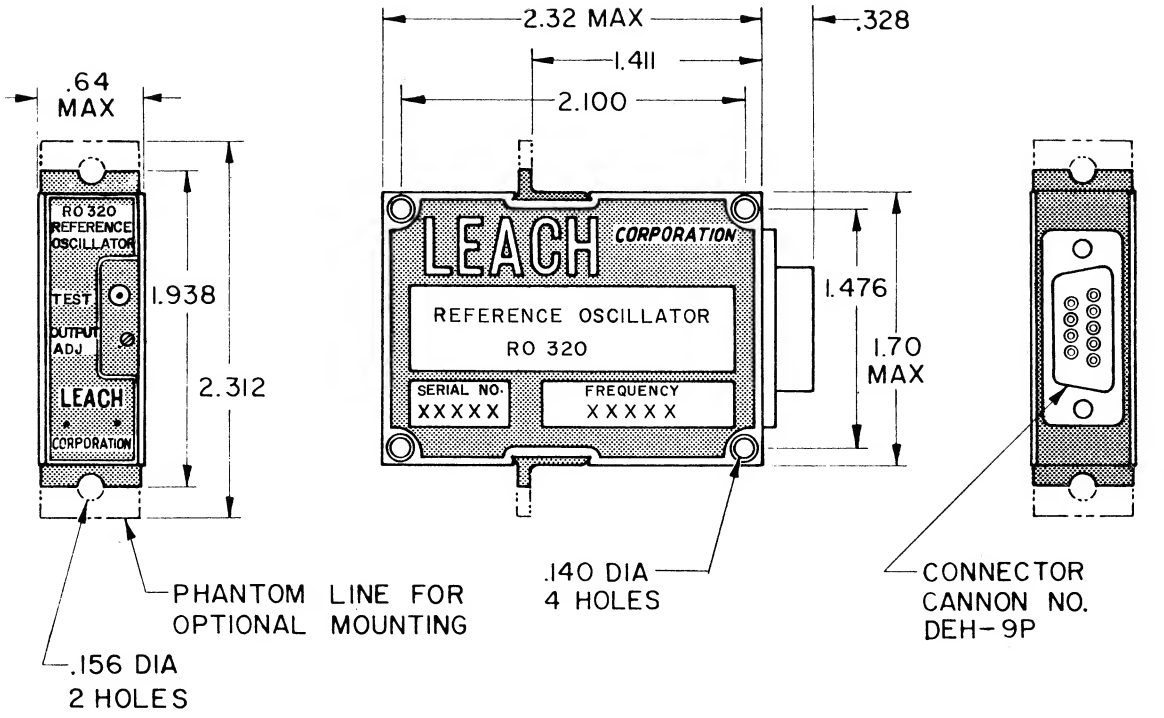
| | |
|---|---|
| Frequency: | 100, 50, 25, 20, 10, 2, 1 kc standard. Other frequencies on special order. |
| Frequency Stability: | ± 0.25% long term over complete environmental range. |
| Output Voltage: | 2 volts rms maximum. |
| Output Impedance: | Less than 400 ohms (Will record direct into standard 1 or 4 mh direct record head) |
| Power Requirements: | 20 volts DC at 15 ma. |
| Controls: | Output control for adjusting output voltage from 0 to 2 volts rms. |
| Test Points: | For frequency monitor. |

### ENVIRONMENTAL SPECIFICATIONS:

| | |
|---|---|
| Temperature: | -40°F to +185°F |
| Shock: | 500 G peak |
| Acceleration: | 200 G |
| Vibration: | 20 G 10 to 2,000 cps |
| Humidity: | 0 to 95% RH |

### MECHANICAL SPECIFICATIONS:

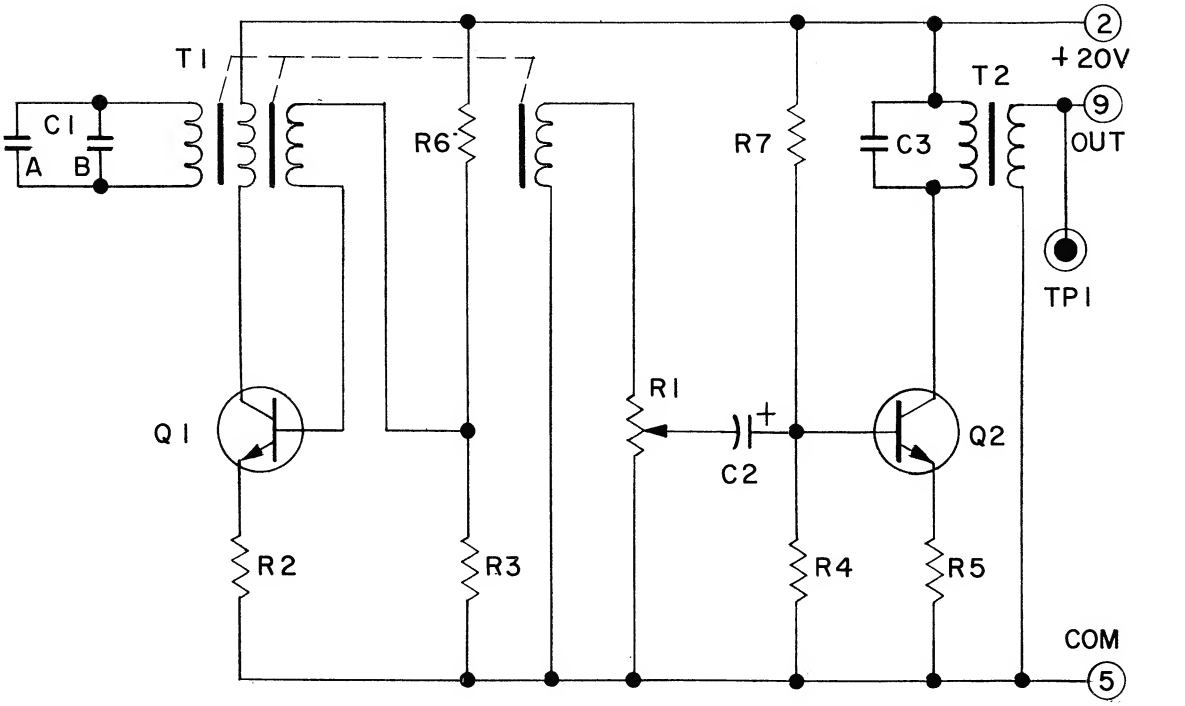
| | |
|---|---|
| Size: | 2,640" x 1.67" x 0.625" including connector. |
| Weight: | 2.75 ounces |
| Electrical Connector: | DEH-9P |
| Part Numbering System: | Basic Number: RO-320 — Frequency kc: 1(1kc Ref. Osc.) |




MODEL NO. **RO 320**

MATING CONNECTOR (NOT FURNISHED)
CANNON DE-9S.

DIMENSIONS NOMINAL UNLESS
OTHERWISE SPECIFIED.




666-37

LEACH CORPORATION

## LEACH MODEL RO-125-100 AND RO-125-50
## REFERENCE OSCILLATOR (CRYSTAL CONTROLLED 100KC or 50KC)

This is a highly stable crystal controlled oscillator at 100kc or 50kc frequencies. It utilizes a solid state silicon design to achieve minimum size and maximum performance under severe environmental conditions.

### ELECTRICAL SPECIFICATIONS:

| | |
|---|---|
| Frequency: | 100kc or 50kc (select desired crystal) |
| Frequency Stability: | At 25°C 100kc ± 10 cps<br>50 kc ± 5 cps |
| Output Volts: | 0 - 2.5 (adjustable) |
| Output Impedance: | Less than 500 ohms (Requires an amplifier to record into a standard 1 or 4 mh magnetic head) |
| Power Requirements: | 20V DC at 8 mils |
| Controls: | Amplitude control to adjust output voltage |

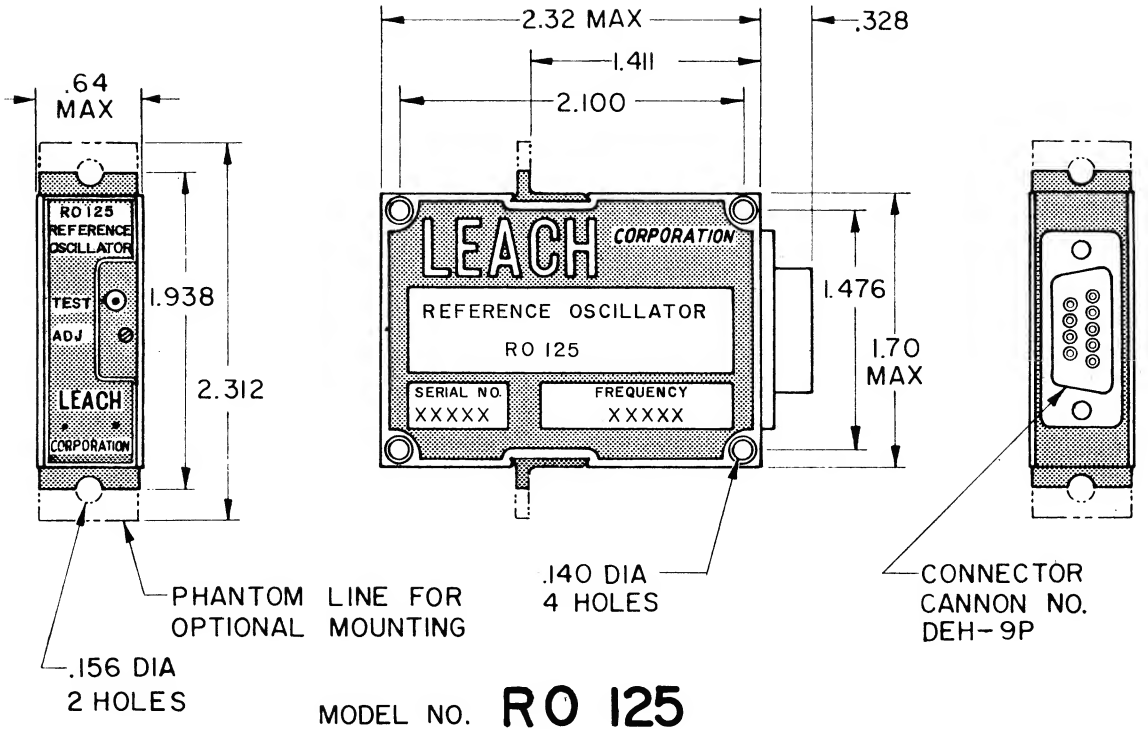
### ENVIRONMENTAL SPECIFICATIONS:

| | |
|---|---|
| Temperature: | -40° to +185°F |
| Shock: | 75 G peak |
| Acceleration: | 100 G |
| Vibration: | 15G or 0.15" DA (whichever is less), 10 to 2,000 cps |
| Humidity: | 0 to 95% relative humidity |

### MECHANICAL SPECIFICATIONS:

| | |
|---|---|
| Size: | 2.640" x 1.67" x 0.625" including connector |
| Weight: | 2.3 ounces |
| Electrical Connector | DEH-9P |
| Part Numbering System: | Basic Number<br>RO-125-100 or RO-125-50 |

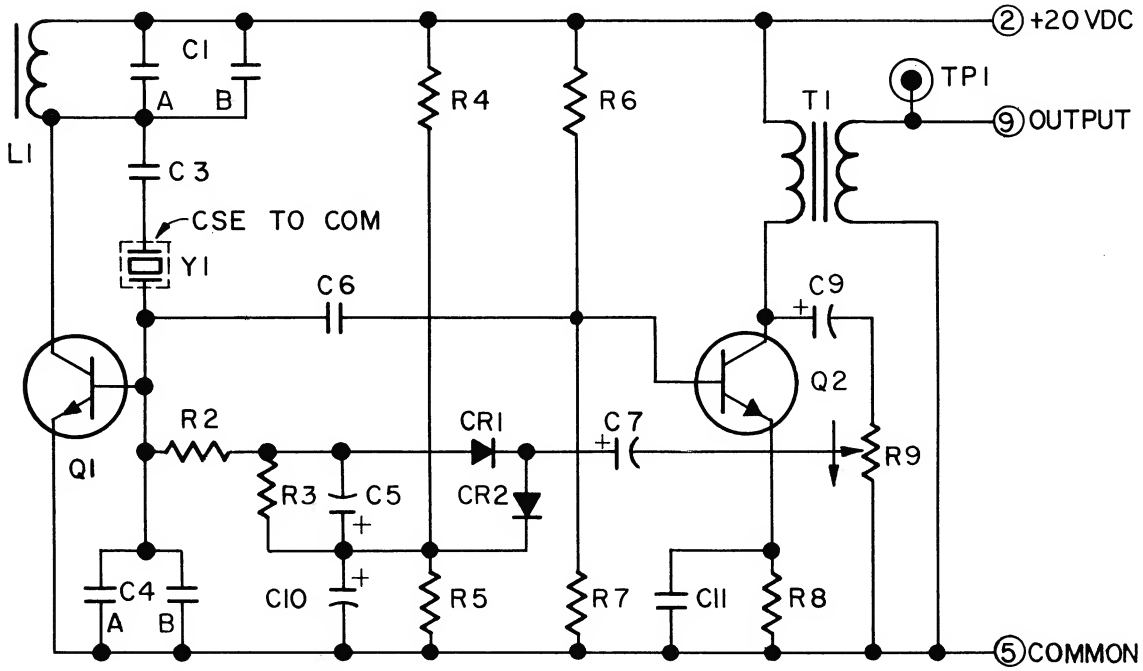
This unit is available at other frequencies above 50kc on special order.




MODEL NO. **RO 125**

MATING CONNECTOR (NOT FURNISHED)
CANNON DE-9S.

ALL DIMENSIONS NOMINAL UNLESS
OTHERWISE SPECIFIED.



LEACH CORPORATION

## LEACH MODEL VR-2420
## VOLTAGE REGULATOR

This is a solid state silicon regulator designed to provide both the voltage regulation and the low source impedance required for stable operation of transistorized Leach record and playback amplifiers, oscillators, etc. It accepts unregulated DC power and provides a regulated output adjustable to 20 volts DC.

### ELECTRICAL SPECIFICATIONS:

| | |
|---|---|
| Input Voltage: | 24-32 volts DC |
| Output Voltage: | 20 volts DC (adjustable ± 2%) |
| Current Capabilities: | 1.0 amp or 0.5 amp |
| Regulation: | Better than 1% for any condition of line, load or temperature. |
| Ripple Reduction Factor: | 20 db |
| Controls: | Voltage adjustable from top of module with slotted screw potentiometer |
| Test Point: | For voltage monitor. |

### ENVIRONMENTAL SPECIFICATIONS:

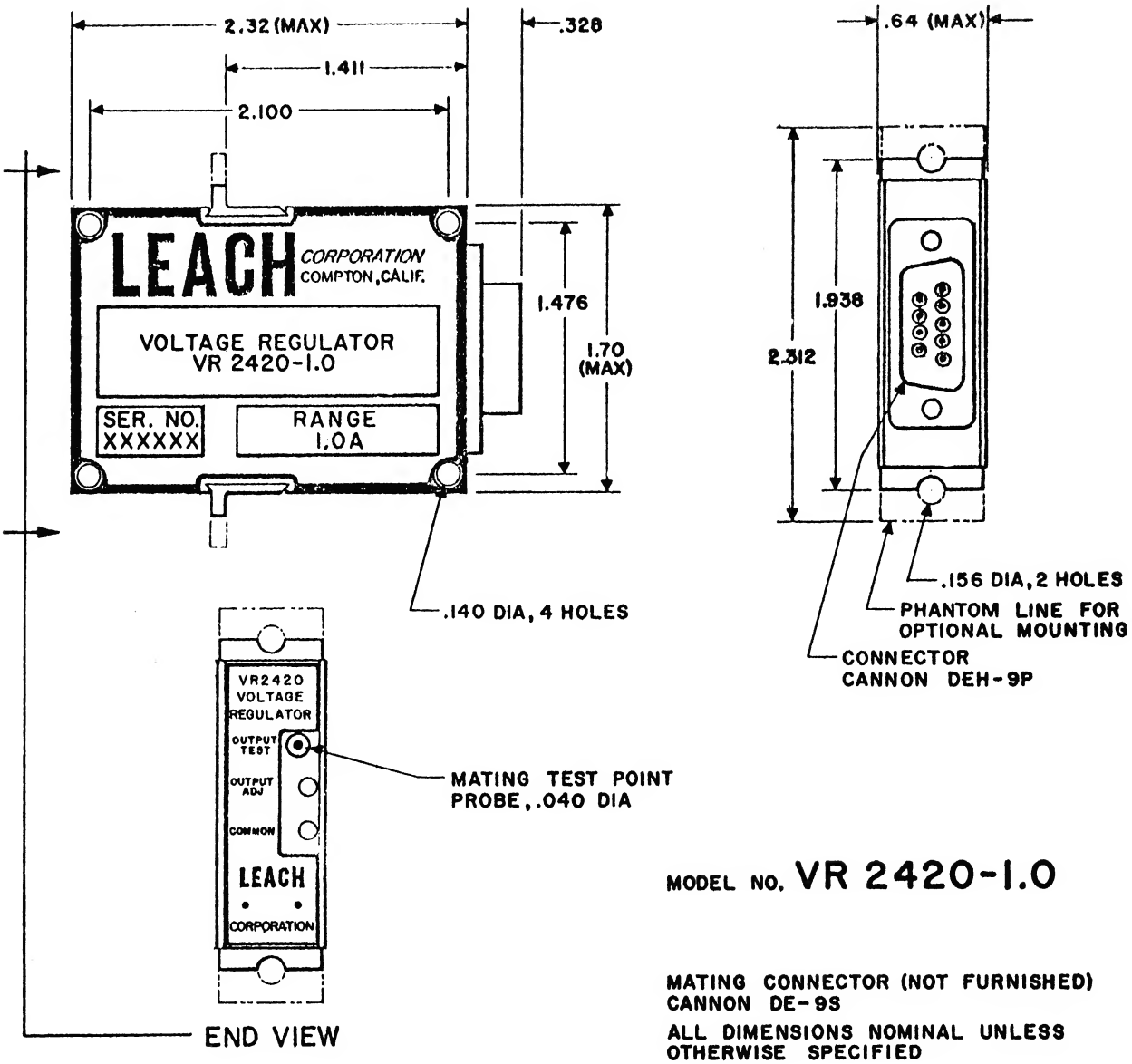
| | |
|---|---|
| Temperature: | -40°F to +185°F |
| Shock: | 500 G Peak |
| Acceleration: | 200 G |
| Vibration: | 20 G 10 to 2,000 cps |
| Humidity: | 0 to 95% RH |

### MECHANICAL SPECIFICATIONS:

| | |
|---|---|
| Size: | 2.640" by 1.670" by 0.625" including connector. |
| Weight: | 2.75 ounces |
| Electrical Connector: | DEH-9P |

Part Numbering System:

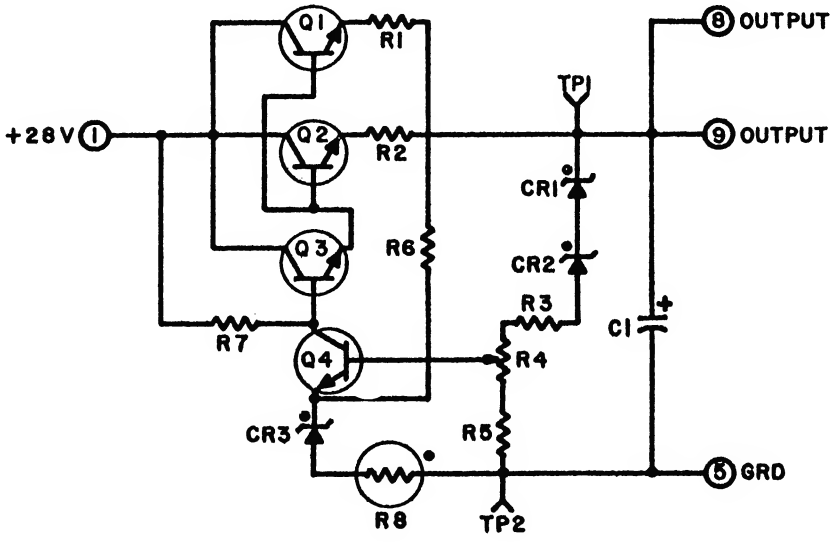
| Basic Number | Current Capabilities in amps |
|---|---|
| VR-2420 | 1.0 |
| VR-2420 | 0.5 |




MODEL NO. **VR 2420-1.0**

MATING CONNECTOR (NOT FURNISHED)
CANNON DE-9S

ALL DIMENSIONS NOMINAL UNLESS
OTHERWISE SPECIFIED




666-41

LEACH CORPORATION

## LEACH MODEL AR-105A
## WIDE BAND FM SUBCARRIER OSCILLATOR

The Model AR-105A, Wide Band FM voltage Controlled Oscillator, converts analog data into frequency modulated signals for recording on magnetic tape. Full scale deviation is ±40 percent for a 5 V p-p input with a square wave output for saturation recording.

### ELECTRICAL SPECIFICATIONS:

| | |
|---|---|
| Input Impedance: | 100 K ohm unbalanced to ground, shunted by 15 pf |
| Back Current: | ±5 amp |
| Sensitivity: | 0 to 5 volts DC or p-p or ±2.5 volts DC (5 volts p-p) for full scale deviation. |
| Frequency Response: | Per chart ±.5 db |
| Drift: | ±1% of bandwidth |
| Linearity: | ±.5% of best straight line |
| Output Impedance: | Dependent on frequency, 500 to 3000 ohms |
| Output Voltage: | Open circuit voltage adjustable up to 26 volts p-p. The unit will provide constant current to saturate record into a 1 mh direct record head. |
| Controls: | Separate controls are incorporated for center frequency adjust, deviation adjust, and output level. |
| Power Requirements: | Regulated +28V DC at 14 ma, -7.5 V DC at 3 ma. |
| Test Point: | For frequency monitor |

| Tape Speed | | | Center Frequency | Maximum Data Frequency |
|---|---|---|---|---|
| Low | Intermediate | High | | |
| 120 | 60 ips | 30 | 108 KC | 20 KC |
| 60 | 30 ips | 15 | 54 KC | 10 KC |
| 30 | 15 ips | 7-1/2 | 27 KC | 5 KC |
| 15 | 7-1/2 ips | 3-3/4 | 13.5 KC | 2500 CPS |
| 7-1/2 | 3-3/4 ips | 1-7/8 | 6.75 KC | 1250 CPS |
| 3-3/4 | 1-7/8 ips | | 3.375 KC | 625 CPS |
| 1-7/8 | | | 1.688 KC | 313 CIS |

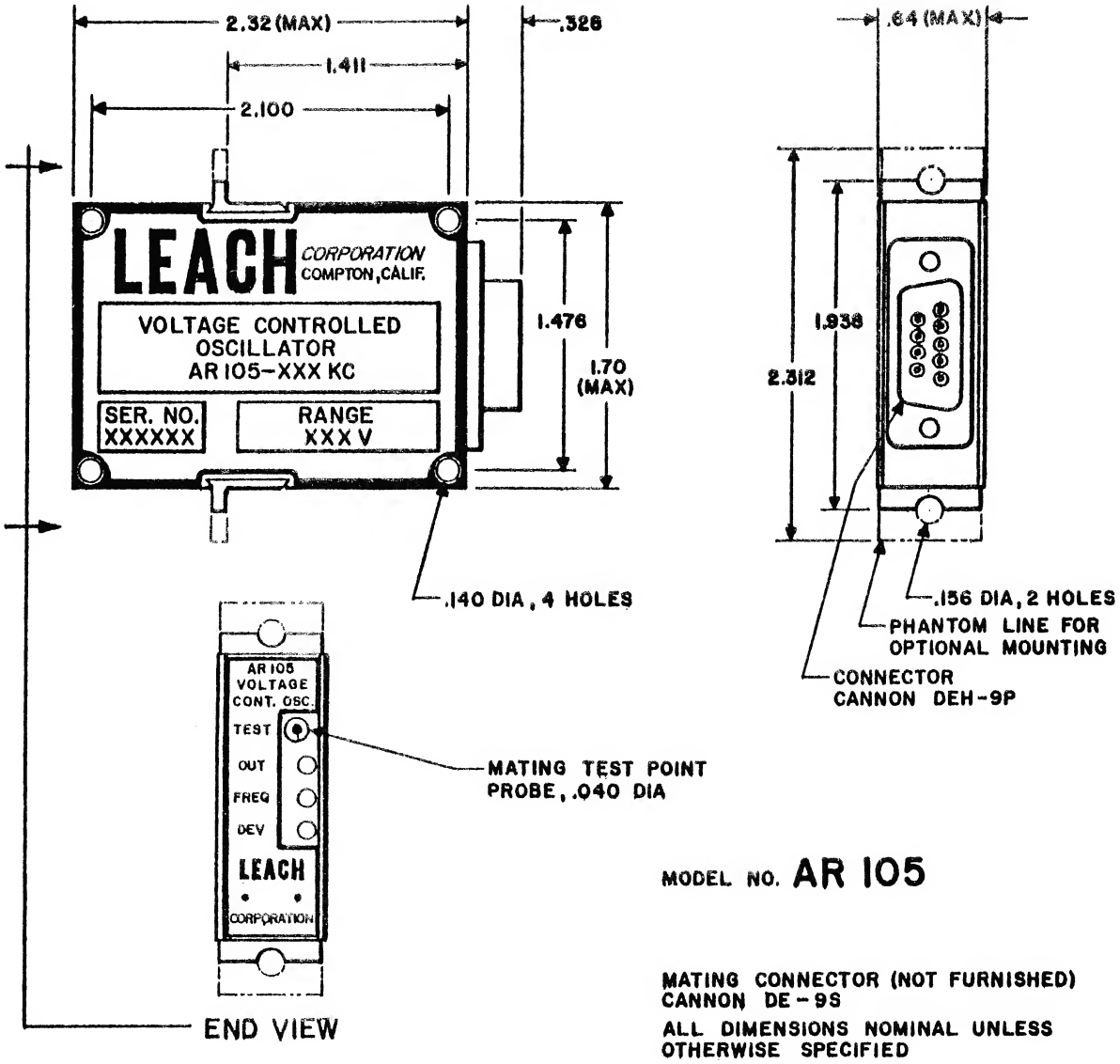
### ENVIRONMENTAL SPECIFICATIONS:

| | |
|---|---|
| Temperature: | -40°F to +185°F |
| Shock: | 500 G Peak |
| Acceleration: | 200 G |
| Vibration: | 20 G, 10 to 2000 cps |
| Humidity: | 0 to 95% RH |

### MECHANICAL SPECIFICATIONS:

| | |
|---|---|
| Size: | 2.640" x 1.67" x 0.625" including connector |
| Weight: | 2.75 ounces |
| Electrical Connector: | DEH-9P |

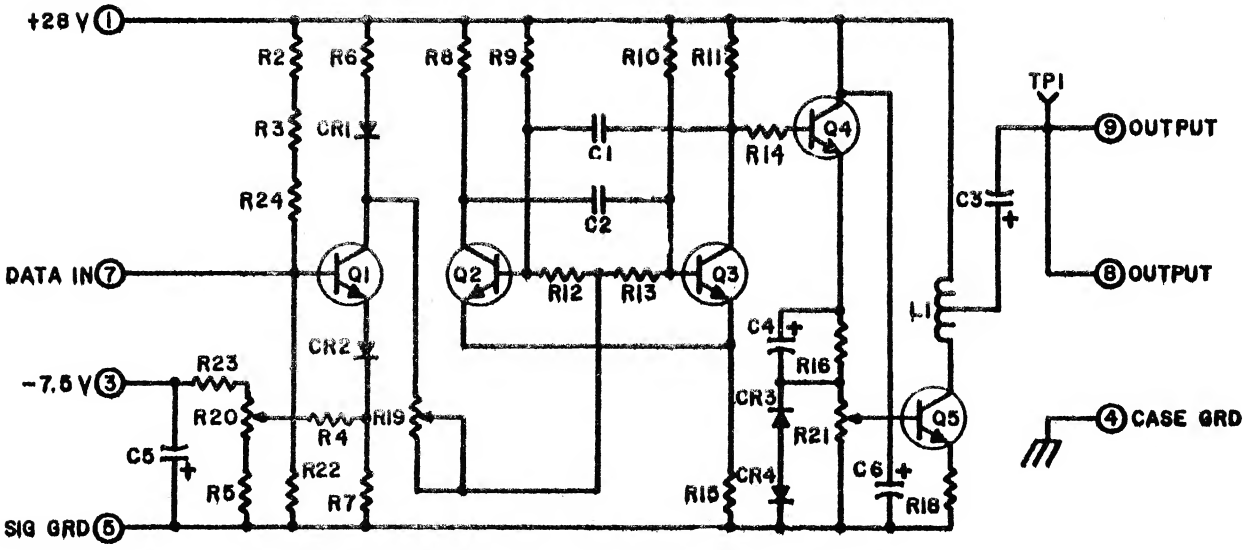
NOTE: Available with internal calibrate relay on special order.




MODEL NO. **AR 105**

MATING CONNECTOR (NOT FURNISHED)
CANNON DE-9S

ALL DIMENSIONS NOMINAL UNLESS
OTHERWISE SPECIFIED



LEACH CORPORATION

## MODEL AT-110
## DIFFERENTIAL DC AMPLIFIER

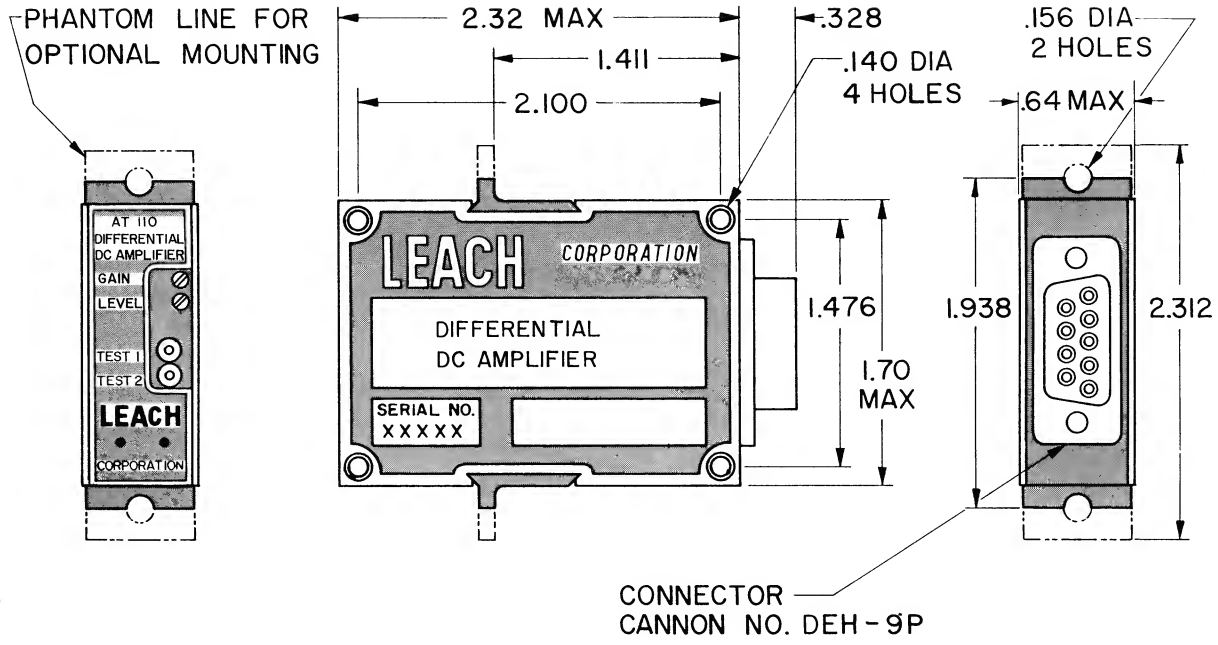
The AT-110 Differential DC Amplifier is a silicon solid state unit primarily designed to provide amplification and impedance matching between 10mv or greater differential input signal sources and voltage controlled oscillators requiring ± 2.5 or 0 to 5 volts for full-scale deviation.

### ELECTRICAL SPECIFICATIONS:

| | |
|---|---|
| Data Input Sensitivity: | Differentially ± 10mv adjustable to ± 50mv |
| Differential Unbalance Correction Range: | ± 300% at ± 10mv input |
| Input Impedance: | Differential greater than 100k |
| Frequency Response: | DC to 10 KC ± 2% |
| Common Mode Rejection: | Better than 80 db to 400 cps |
| Common Mode DC Range: | -2 volts to + 10 volts |
| Linearity: | Better than 1% |
| Harmonic Distortion: | Less than 1% |
| Drift: | ± 0.1 millivolts referred to the input for 8 hours (less than 1.5% peak to peak over temperature range). |
| Signal Output: | Up to ± 5 volts |
| Output Zero Level: | Adjustable between ± 5v with respect to common |
| Output Impedance: | 3 k ohms singled ended |
| Power Requirements: | +28 volts at 7.5 ma & -7.5 volts at 7.5 ma (matched regulated power supplies are available). |
| Controls: | Zero level balance and gain |
| Temperature: | -40 to 85° C |
| Shock: | 500 G Peak |
| Acceleration: | 200 G Peak |
| Vibration: | 20 G 10 to 2,000 cps |

### MECHANICAL SPECIFICATIONS:

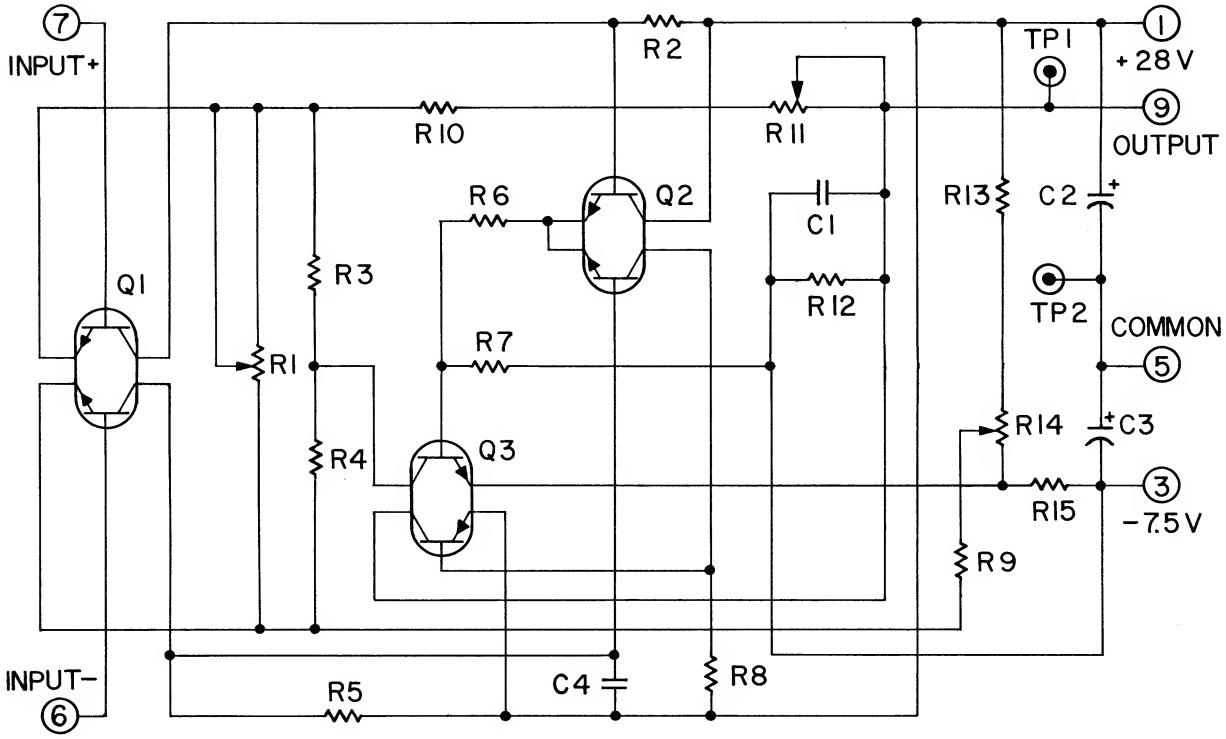
| | |
|---|---|
| Size: | 2.640" by 1.670" by 0.625" including connector |
| Weight: | 2.75 ounces |
| Electrical Connector: | DEH-9P |




## MODEL NO. AT 110

MATING CONNECTOR (NOT FURNISHED)
CANNON DE-9S.

DIMENSIONS NOMINAL UNLESS
OTHERWISE SPECIFIED.



LEACH CORPORATION

## LEACH MODEL AR-116
## LOW LEVEL FM RECORD AMPLIFIER

The Model AR-116, low level FM record amplifier, converts analog data into frequency modulated signals for recording on magnetic tape. Full scale deviation is ±40 percent with a square wave output for saturation recording.

### ELECTRICAL SPECIFICATIONS:

| | |
|---|---|
| Input Impedance: | Differential greater than 100 K |
| Data Input Sensitivity: | ± 10 mv adjustable to ± 50 mv |
| Differential Unbalance Correction Range: | ± 300 percent at ± 10 mv input |
| Common Mode Rejection: | Greater than 80 db at 400 cps |
| Common Mode DC Range: | -1.5 v to +15 v |
| Drift: | ±0.064 mv/°C over temperature range -40°C to +85°C |
| Linearity: | ± 1 percent of Best Straight Line |
| Output: | Open circuit voltage adjustable up to 27 v p/p. Output capable of driving a 1 mh record head |
| Controls: | Center frequency, deviation (coarse and fine) and output |
| Power Requirements: | Regulated +28 v at 25 ma -7.5 v at 22 ma |

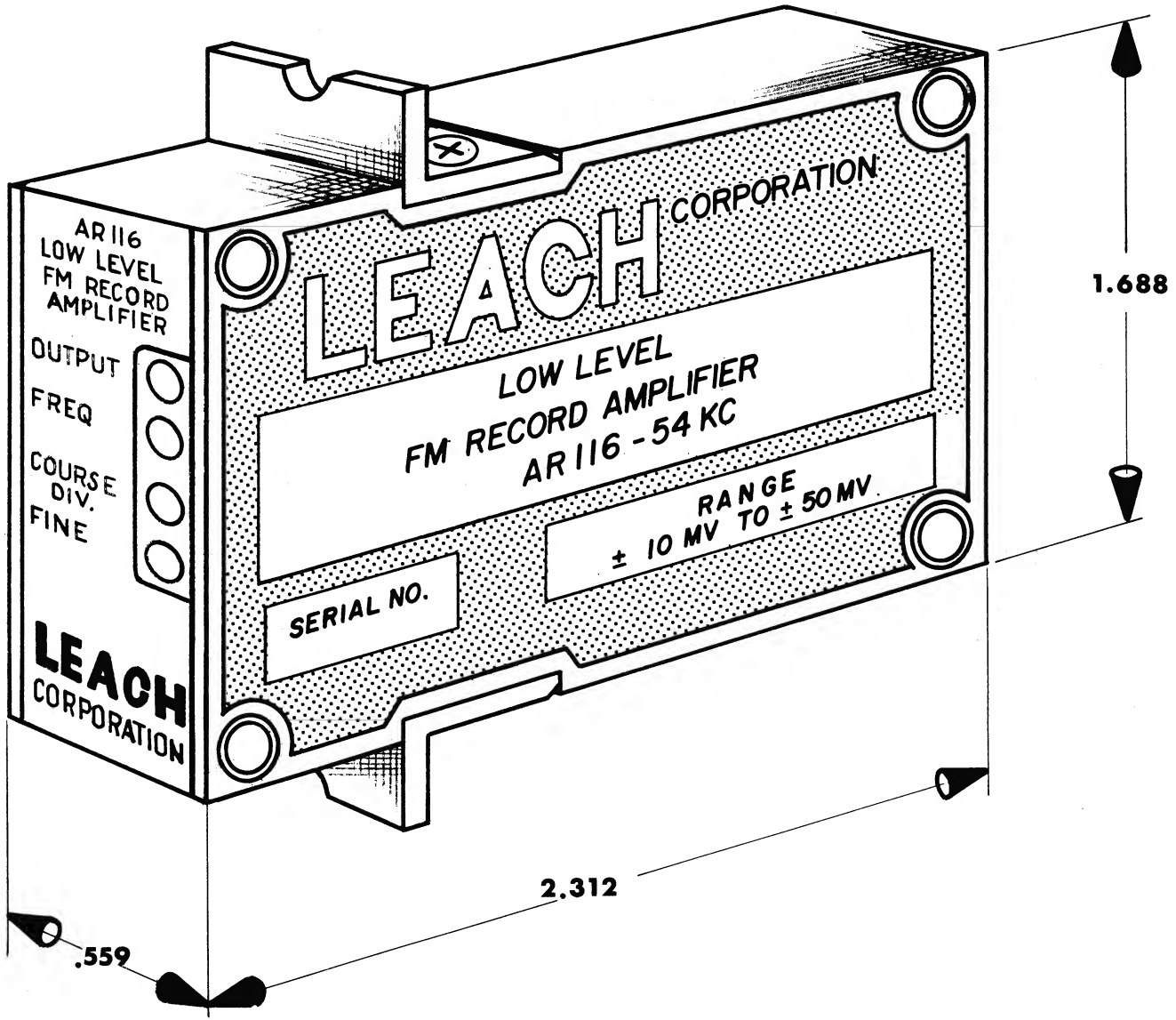
| Tape Speed | Center Frequency | Maximum Data Frequency |
|---|---|---|
| 60 ips | 54 KC | 10 KC |
| 30 ips | 27 KC | 5 KC |
| 15 ips | 13.5 KC | 2500 cps |
| 7-1/2 ips | 6.75 KC | 1250 cps |
| 3-3/4 ips | 3.375 KC | 625 cps |

### ENVIRONMENTAL SPECIFICATIONS:

| | |
|---|---|
| Temperature: | -40°F to +185°F |
| Shock: | 500 G peak |
| Acceleration: | 200 G |
| Vibration: | 20 G 10 to 2,000 cps |
| Humidity: | 0 to 95% RH |

### MECHANICAL SPECIFICATIONS:

| | |
|---|---|
| Size: | 2.640" x 1.67" x 0.625" including connector |
| Weight: | 2.75 ounces |
| Electrical Connector: | DEH-9P |




FM RECORD AMPLIFIER - AR 116

LEACH CORPORATION

## LEACH MODEL PS-305A
## POWER SUPPLY

The PS-305A, power supply, is a precision regulator unit which utilizes the latest in silicon semiconductor design for overall stability. This power supply is primarily for use with the AR-105 voltage controlled oscillators and the AT-110 DC amplifier. The PS-305A has the power capability for 14 each of these units. Full isolation between input and output is provided to permit optional grounding. Input polarity reversal safety is incorporated.

### ELECTRICAL SPECIFICATIONS:

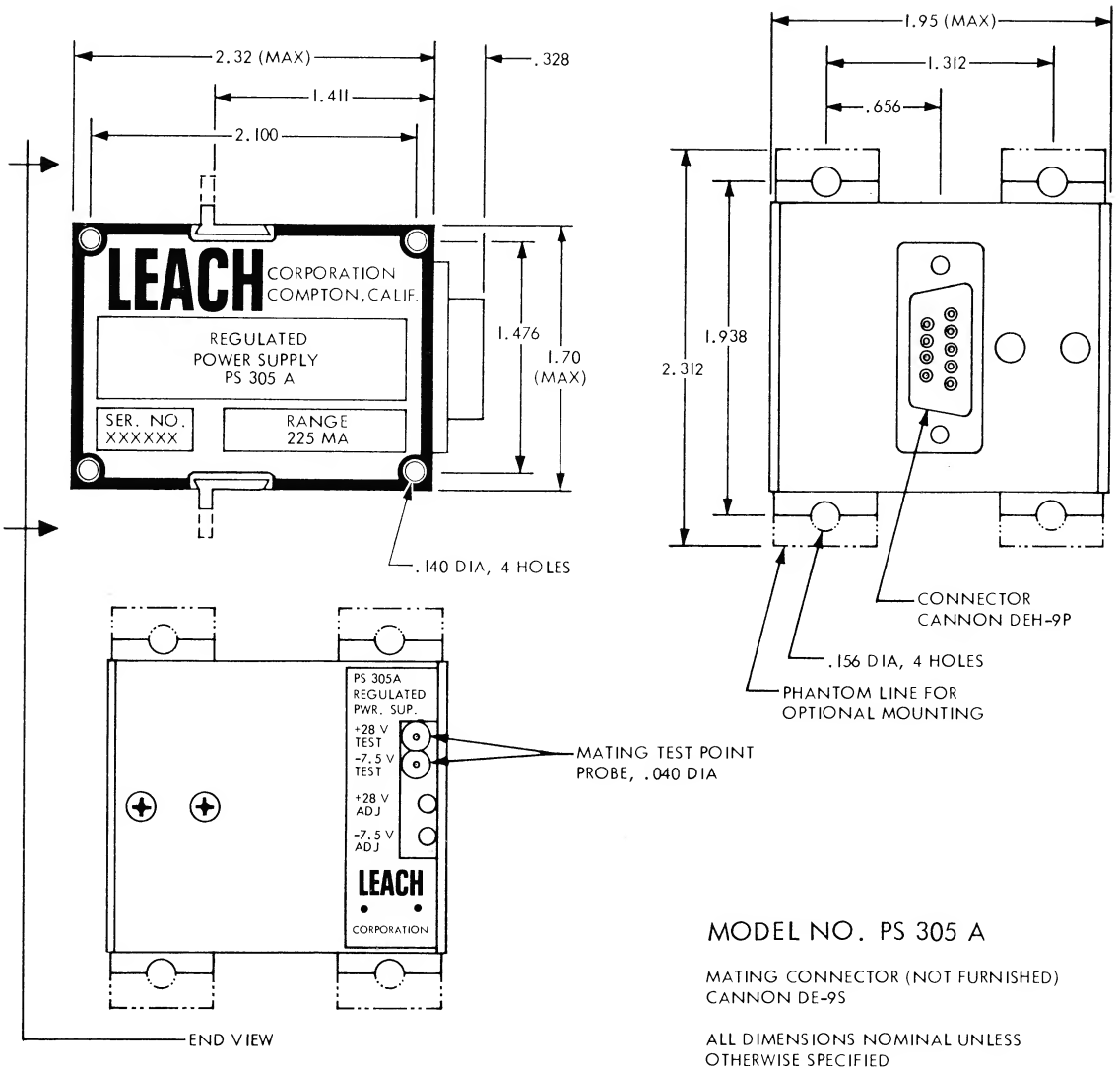
| | |
|---|---|
| Input Voltage: | 24 to 32 volts DC. |
| Output Power: | +28 volts DC regulated at 225 ma<br>-7.5 volts DC regulated at 115 ma. |
| Output Ripple: | Less than 10 mv rms. |
| Line Transients: | Less than 30 mv p-p into a 1 ohm source. |
| Regulation: | $\pm$ 0.25% |
| Controls: | Potentiometer for +28 and -7.5 adjust. |
| Test Points: | For output voltage monitor of +28 and -7.5. |

### ENVIRONMENTAL SPECIFICATIONS:

| | |
|---|---|
| Temperature: | -40°F to +185°F |
| Shock: | 500 G peak |
| Acceleration: | 200 G |
| Vibration: | 20 G 10 to 2,000 cps. |
| Humidity: | 0 to 95% RH |

### MECHANICAL SPECIFICATIONS:

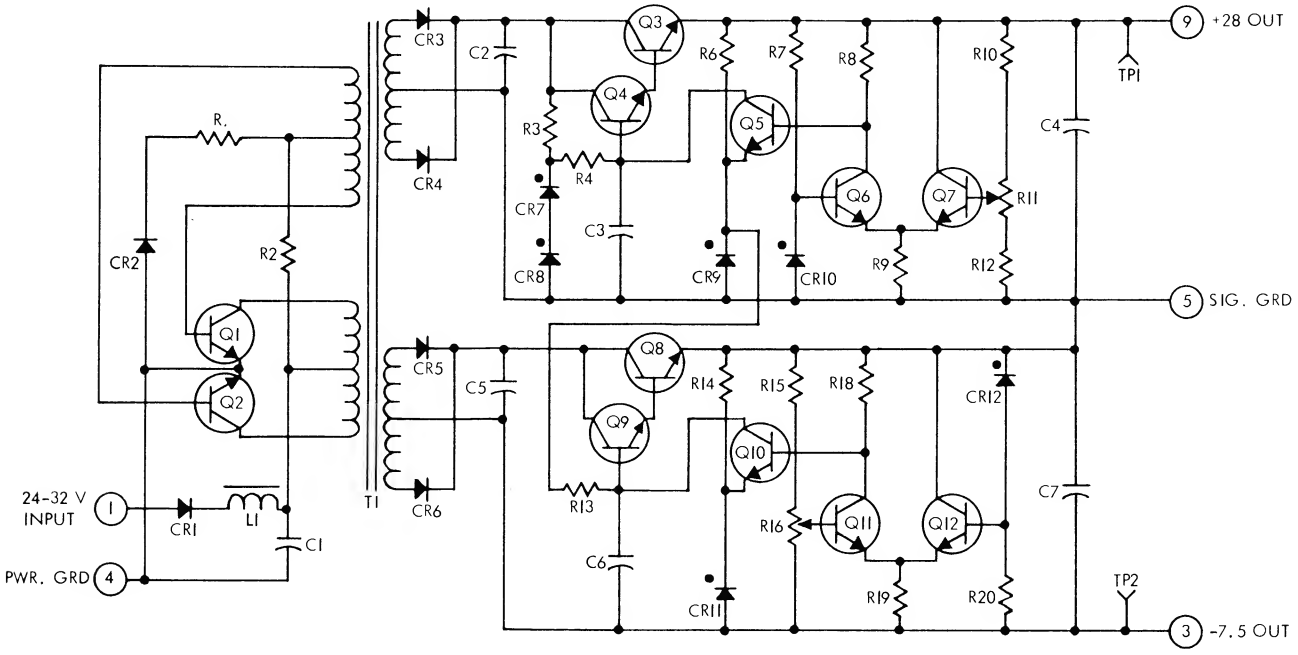
| | |
|---|---|
| Size: | 2.640" by 1.670" by 2.0" including connector. |
| Weight: | 8.5 ounces |
| Electrical Connector: | DEH-9P |
| Part Numbering System: | Basic Number<br>PS-305A |




## MODEL NO. PS 305 A

MATING CONNECTOR (NOT FURNISHED)
CANNON DE-9S

ALL DIMENSIONS NOMINAL UNLESS
OTHERWISE SPECIFIED



## LEACH MODEL IR-404
## INVERTER REGULATOR

The IR-404, Static Inverter-Regulator, is used to provide a precise 400 cycle power to the PC-203, Phase Control Unit, which provides power factor and phase corrections to the 28 VAC 400 cycle hysteresis synchronous motor in the Leach MTR series tape recorders. The frequency of this unit is adjustable over a narrow range and is set to operate the tape transport motor at the proper RPM to result in an accurate tape speed. This unit has high reserve power capabilities to insure fast recorder starts and its primary use is with the 60 ips MTR 800 and MTR-1200 Recorder.

### ELECTRICAL SPECIFICATIONS:

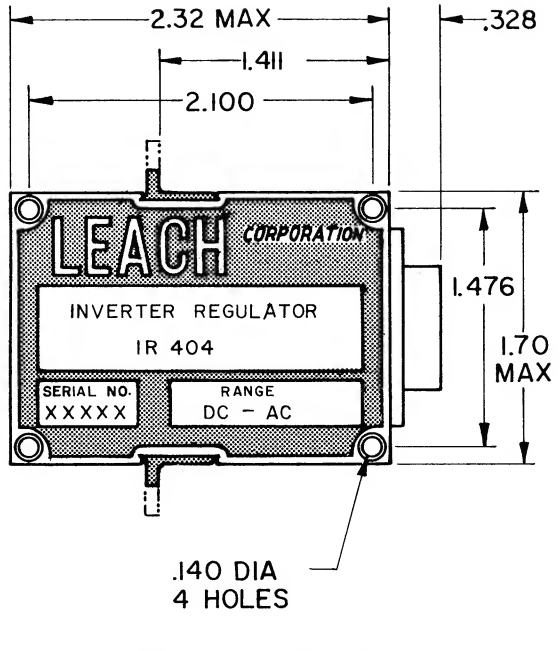
| | |
|---|---|
| Frequency: | 400 cps ± 0.5% +32°F to +165°F<br>400 cps ± 1.0% -40°F to +165°F |
| Output Voltage: | 28 V AC square wave non-isolated |
| Input Voltage: | 28 V DC ± 10% |
| Current Requirements: (Normal Operation) | 3.0 AMPS |
| Power output maximum: | 180 watts Resistive Load<br>125 watts Inductive Load |
| Efficiency: | 75% with PC-203 |
| Controls: | Potentiometer for frequency adjust ± 3% |
| Test Point: | Frequency Monitor |

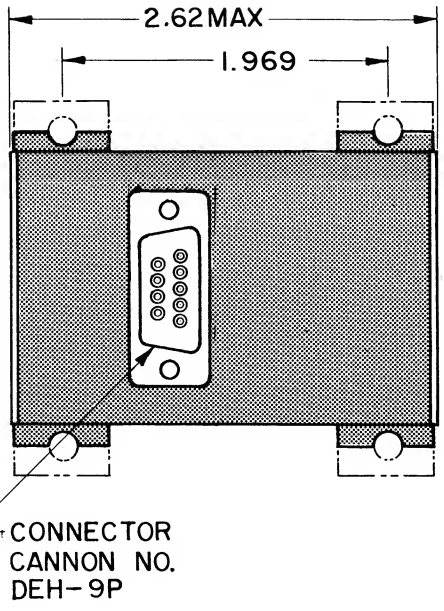
### ENVIRONMENTAL SPECIFICATIONS:

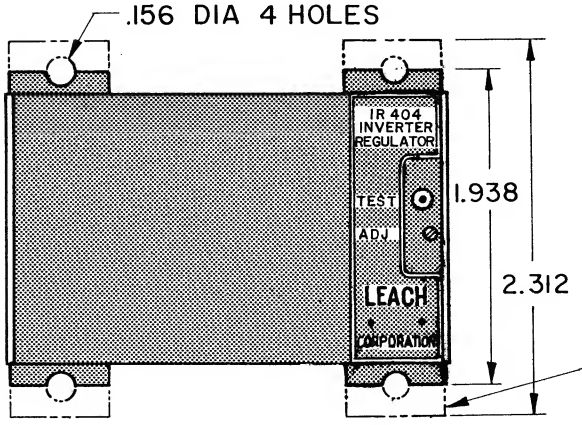
| | |
|---|---|
| Temperature: | -40°F to +165°F continuous to +185°F with intermittent operation of 5 minutes on, 15 minutes off. |
| Shock: | 500 G |
| Acceleration: | 200 G |
| Vibration: | 20 G, 10 to 2,000 cps |

### MECHANICAL SPECIFICATIONS:

| | |
|---|---|
| Size: | 2.640" by 1.670" by 2.560" including connector |
| Weight: | 12 ounces |
| Electrical Connector: | DEH-9P |
| Part Numbering System: | Basic Number<br>IR-404 |



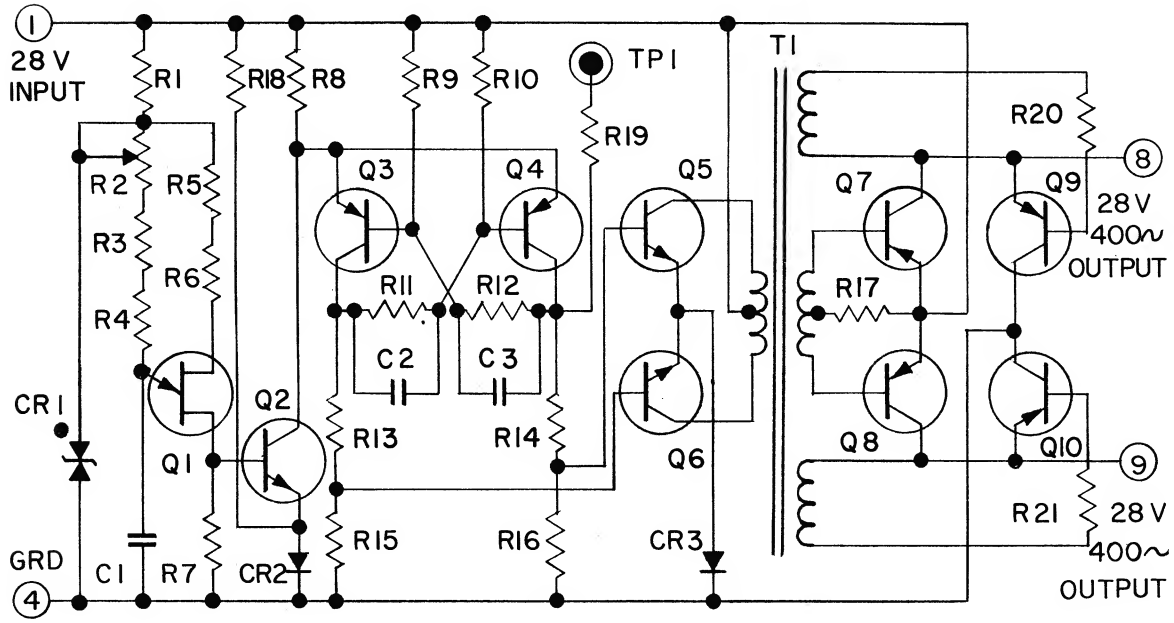




MODEL NO. **IR 404**

MATING CONNECTOR
(NOT FURNISHED)
CANNON DE-9S.

DIMENSIONS NOMINAL UNLESS
OTHERWISE SPECIFIED.

PHANTOM LINE FOR
OPTIONAL MOUNTING



LEACH CORPORATION

## LEACH MODEL PC 203
## PHASE CONTROL ASSEMBLY

The Phase Control Assembly is designed to accept the 28V AC 400 cycle voltage from the IR 404 Inverter Regulator. It provides a 90° phase shift output and an output without phase shift to power a 28V AC two phase hysteresis synchronous motor used in the tape transport. A jumper is connected across the power factor terminal when the motor is connected. This connects capacitors in parallel with the windings to correct the power factor.

### ELECTRICAL SPECIFICATIONS:

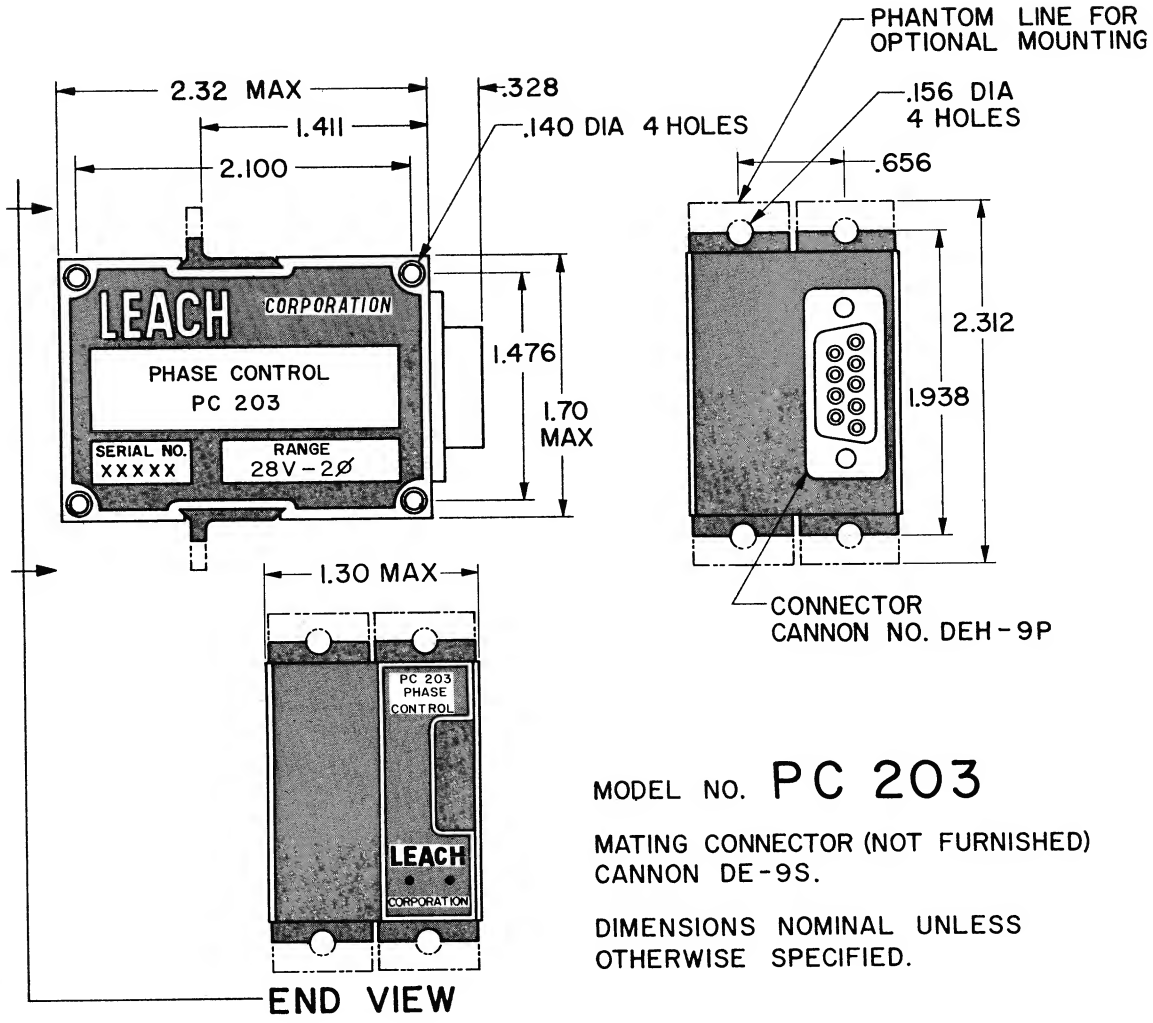
| | |
|---|---|
| Input Voltage: | 28 volts AC 400 cycle square waves |
| Output Voltages: | 28 volts AC 400 cycles |
| Phasing: | Direct line output the same as the input<br>phase correction output leads 90° |
| Power Factor: | Power Factor is corrected by connecting<br>a jumper across the output terminals. |

### ENVIRONMENTAL SPECIFICATIONS:

| | |
|---|---|
| Temperature: | -40° to +165°F |
| Shock: | 500 G's peak |
| Acceleration: | 200 G's |
| Vibration: | 20 G's, 10 to 2,000 cps |
| Humidity: | 0 to 95% relative humidity |

### MECHANICAL SPECIFICATIONS:

| | |
|---|---|
| Size: | 2.640" x 1.670" x 1.25" including connector |
| Weight: | 7 ounces |
| Electrical Connector: | DEH-9P |
| Part Numbering System: | Basic Number<br>PC-203 |




MODEL NO. PC 203

MATING CONNECTOR (NOT FURNISHED)
CANNON DE-9S.

DIMENSIONS NOMINAL UNLESS
OTHERWISE SPECIFIED.

LEACH CORPORATION

## LEACH MODEL LF-201
## LINE FILTER

This filter is used in conjunction with the IR301, TP301, IR404 and PC203 to prevent switching transients from appearing on the 28 VDC source. High density packaging techniques are employed utilizing modern miniaturized components.

### ELECTRICAL SPECIFICATIONS:

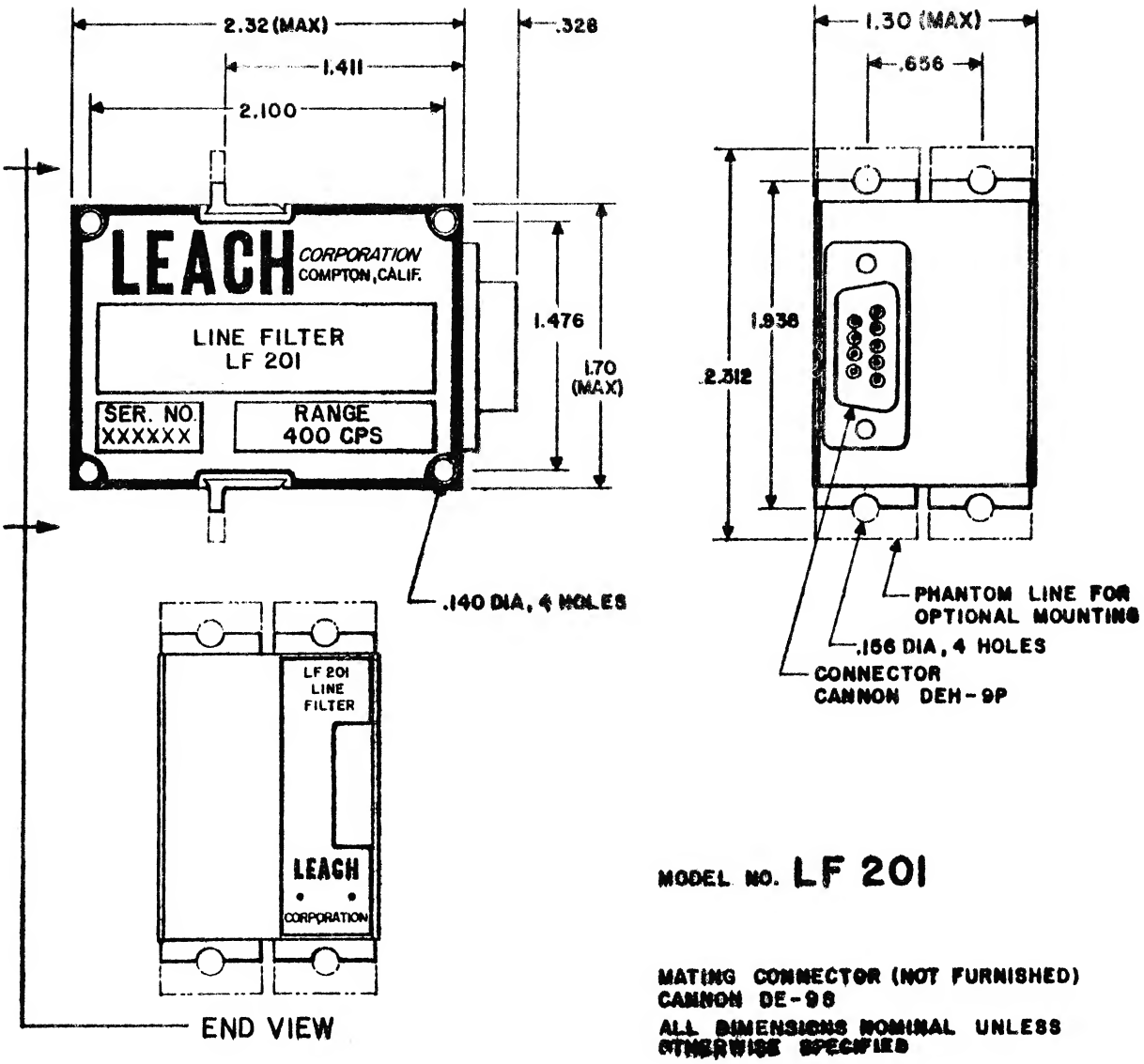
| | |
|---|---|
| Input Voltage: | 28 VDC nominal |
| Output Load: | IR-301 or IR-404 Inverter |
| Transient Reduction: | Less than 50 mv p-p reflected into a 1 ohm source impedance. |

### ENVIRONMENTAL SPECIFICATIONS:

| | |
|---|---|
| Temperature: | -40°F to +185°F |
| Shock: | 500 G peak |
| Acceleration: | 200 G |
| Vibration: | 20 G, 10 to 2,000 cps |
| Humidity: | 0 to 95% RH |

### MECHANICAL SPECIFICATIONS:

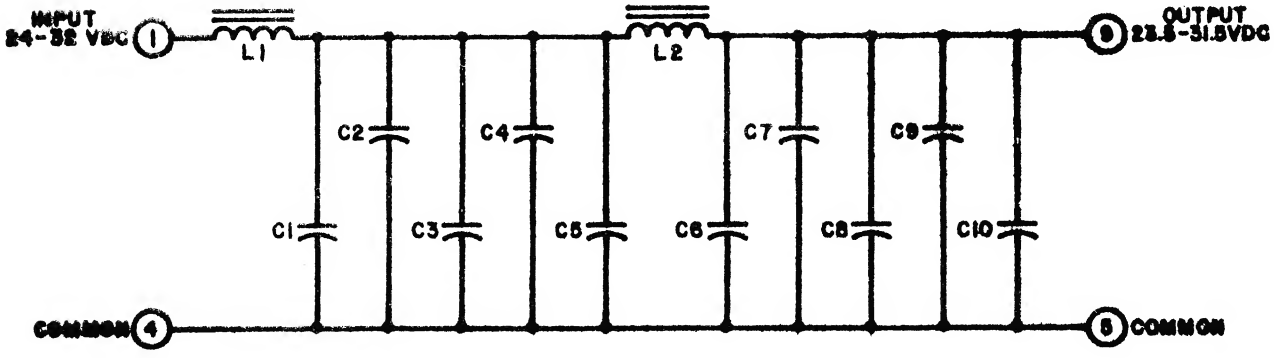
| | |
|---|---|
| Size: | 2.64" by 1.670" by 1.25" including connector. |
| Weight: | 6 ounces |
| Electrical Connector: | DEH-9P |
| Part Numbering System: | Basic Number<br>LF-201 |




MODEL NO. **LF 201**

MATING CONNECTOR (NOT FURNISHED)
CANNON DE-9S

ALL DIMENSIONS NOMINAL UNLESS
OTHERWISE SPECIFIED



LEACH CORPORATION

## LEACH MODEL EP-101

## EQUALIZER PLAYBACK AMPLIFIER

The equalizer playback amplifier incorporates modern silicon solid state design with stable passive elements to provide the required preamplification and equalization from a Leach reproduce head. The frequency response is inverse to the normal reproduce head curve when recording is accomplished using the standard IRIG direct record parameters. The EP-101 will also provide the required preamplification and equalization for extended bandwidth recording.

The output of the EP-101 is used to drive the input of the AP-101, Wide Band Amplifier, which provides the additional gain and low output impedance required for satisfactory reproduce system operation.

### ELECTRICAL SPECIFICATIONS:

| | |
|---|---|
| Input Impedance: | Dependant on frequency. |
| Output Impedance: | 200 ohms at 1 kc. |
| Gain: | 140 at 50 cps. |
| Power Requirements: | +20 volts DC at 10 ma. |
| Frequency Response: | ±2 db per table (± 3 db at 50 cps) |
| Signal to Noise Ratio: | -50 db |
| Harmonic Distortion: | Less than 1% total for MID-RANGE and HIGH RANGE equalization. |
| Test Point: | For output voltage monitor |

### ENVIRONMENTAL SPECIFICATIONS:

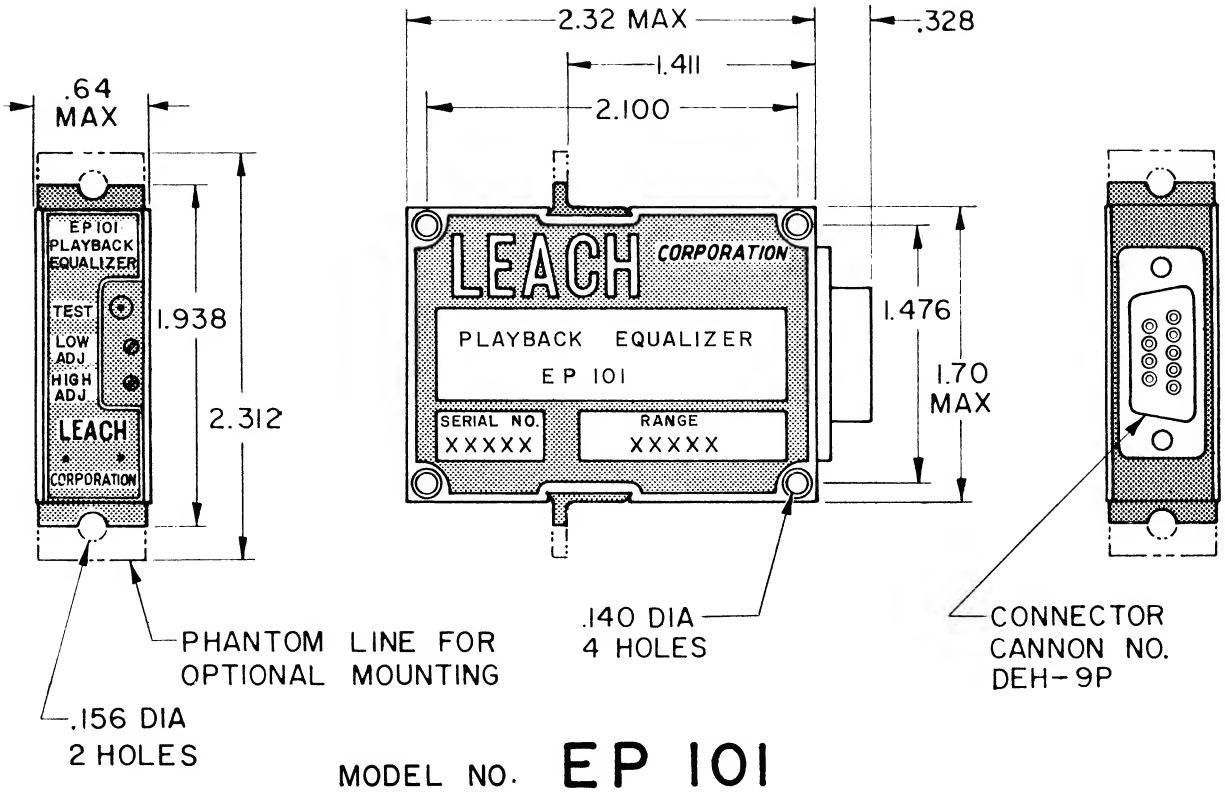
| | |
|---|---|
| Temperature: | -40°F to +185°F |
| Shock: | 500 G peak |
| Acceleration: | 200 G |
| Vibration: | 20 G, 10 to 2,000 cps |
| Humidity: | 0 to 95% RH |

### MECHANICAL SPECIFICATIONS:

| | |
|---|---|
| Size: | 2.64" by 1.670" by 0.625" including connector |
| Weight: | 2.75 ounces |
| Electrical Connector: | DEH-9P |

Part Numbering System:

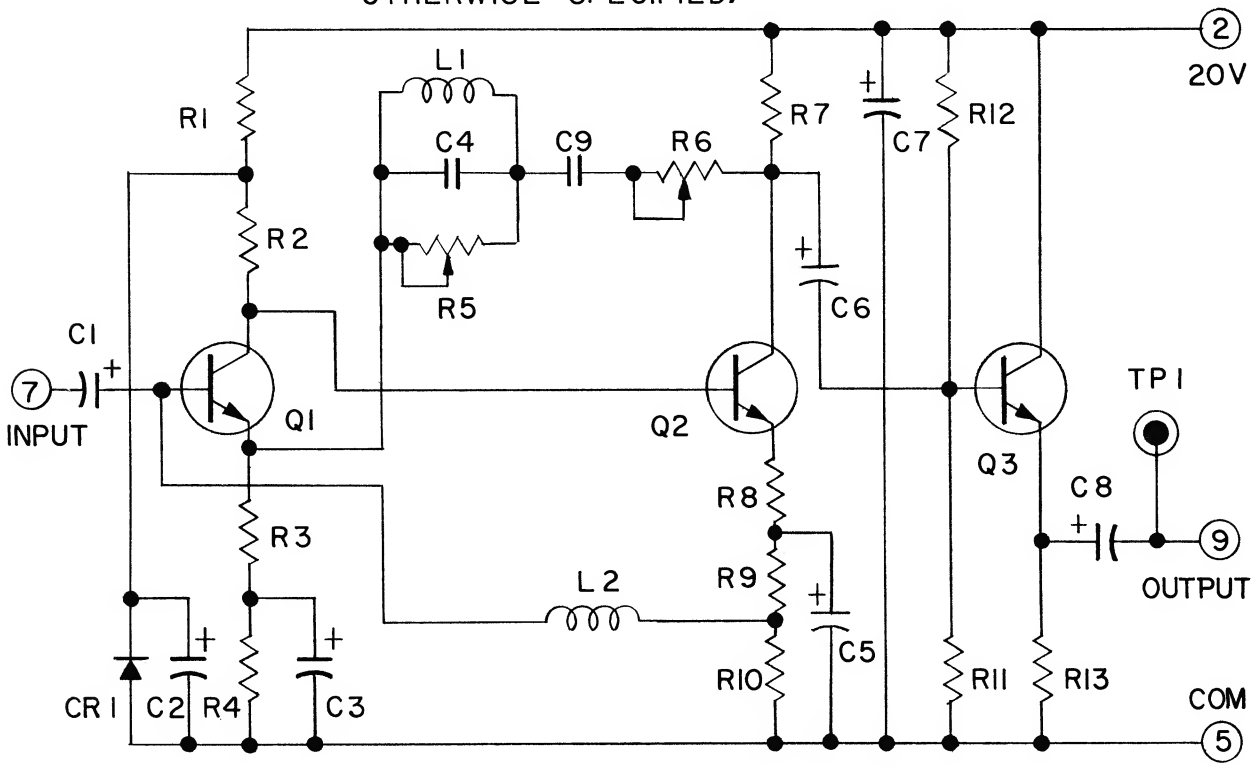
| Basic Number | Tape Speed | Extended Bandwidth |
|---|---|---|
| EP-101 | -60 (60 ips) | -60 (30 ips) |




MODEL NO. **EP 101**

MATING CONNECTOR (NOT FURNISHED)
CANNON DE-9S.

DIMENSIONS NOMINAL UNLESS
OTHERWISE SPECIFIED.




666-57

LEACH CORPORATION

## LEACH MODEL AP-101
## AMPLIFIER PLAYBACK

This playback amplifier is a stable silicon solid state design with a wide frequency response for use with the Leach EP-101, Equalizer Preamplifier. The unit provides a high gain and low output impedance for satisfactory analog reproduction.

### ELECTRICAL SPECIFICATIONS:

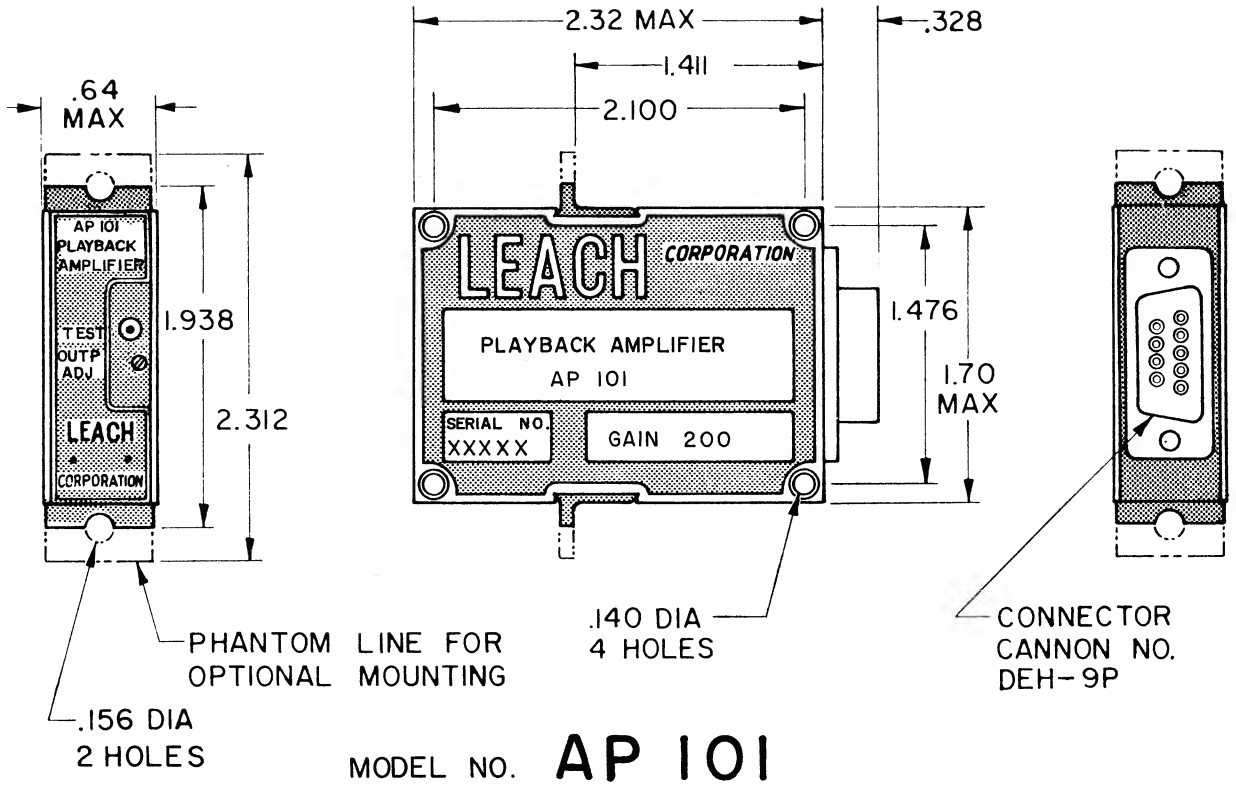
| | |
|---|---|
| Input Impedance: | 10,000 ohms |
| Output Impedance: | Less than 1,000 ohms |
| Gain: | 250 maximum |
| Output: | 1 volt rms when used with Leach EP-101 into 10,000 ohms |
| Frequency Response: | 50 cps to 100 kc ± 0.5 db |
| Harmonic Distortion: | Less than 1% total with EP-101. |
| Power Requirements: | +20 volts DC at 5 ma. |
| Controls: | Potentiometer for gain adjust |
| Test Point: | For output voltage monitor. |

### ENVIRONMENTAL SPECIFICATIONS:

| | |
|---|---|
| Temperature: | -40°F to +185°F |
| Shock: | 500 G peak |
| Acceleration: | 200 G |
| Vibration: | 20 G, 10 to 2,000 cps |
| Humidity: | 0 to 95% RH |

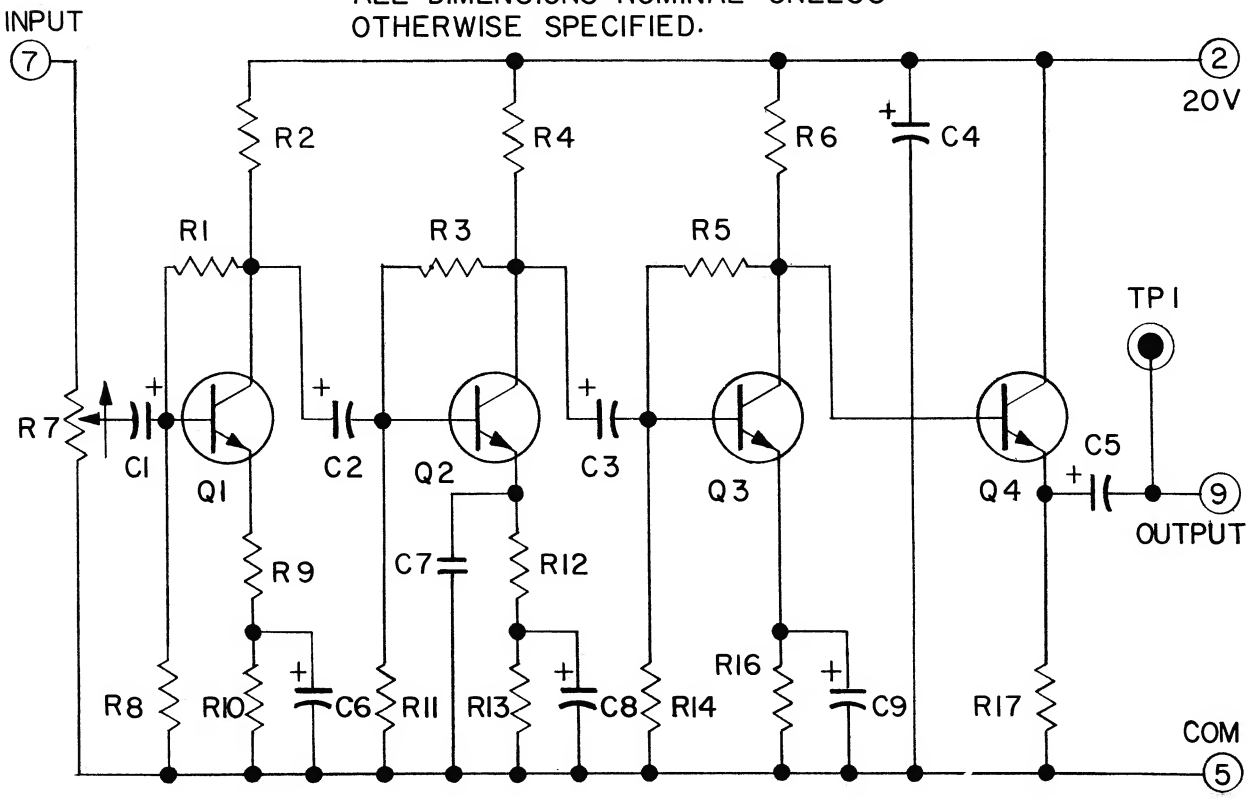
### MECHANICAL SPECIFICATIONS:

| | |
|---|---|
| Size: | 2.64" by 1.670" by .625" including connector |
| Weight: | 2.75 ounces |
| Electrical Connector: | DEH-9P |
| Part Numbering System: | Basic Number<br>AP-101 |




MODEL NO. **AP 101**

MATING CONNECTOR (NOT FURNISHED)
CANNON DE-9S.
ALL DIMENSIONS NOMINAL UNLESS
OTHERWISE SPECIFIED.




666-59

LEACH CORPORATION

## LEACH MODEL IR-402

## ISOLATION DC-DC CONVERTER

This efficient solid state converter is primarily used to offer power to signal ground isolation in Leach recording systems. The design requires that it be used with the voltage regulator Model VR-2420 for maximum performance. The converter incorporates input and output filtering to minimize overall system transient and ripple noise. Input polarity reversal safety is incorporated.

### ELECTRICAL SPECIFICATIONS:

| | |
|---|---|
| Input Voltage: | 24 to 32 volts DC |
| Output Voltage: | 23 to 34 volts DC at 1 ampere load<br>25 to 32 volts DC at no load. |
| Power: | 32 watts maximum |
| Line Transients: | Less than 100 mv p-p into a 1 ohm power supply source impedance. |
| Output Transients and Ripple: | Less than 100 mv p-p. |
| Efficiency: | 80 ± 5% |
| Test Points: | For plus and minus voltage monitor. |

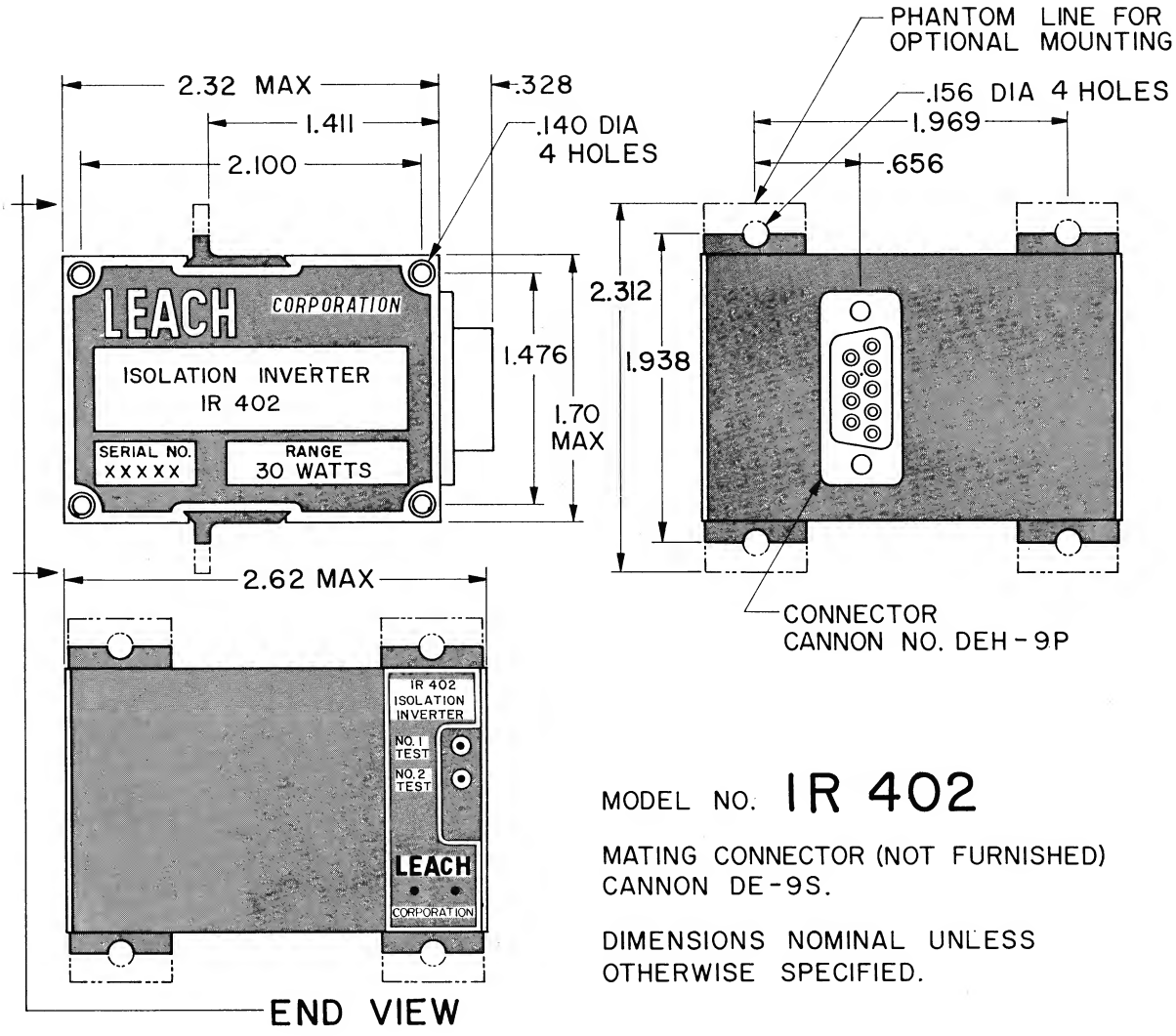
### ENVIRONMENTAL SPECIFICATIONS:

| | |
|---|---|
| Temperature: | -40°F to +185°F |
| Shock: | 500 G peak |
| Acceleration: | 200 G |
| Vibration: | 20 G, 10 to 2,000 cps |
| Humidity: | 0 to 95% RH |

### MECHANICAL SPECIFICATIONS:

| | |
|---|---|
| Size: | 2.64" by 1.67" by 2.65" including connector. |
| Weight: | 9.0 ounces |
| Electrical Connector: | DEH-9P |
| Part Numbering System: | Basic Number<br>IR - 402 |

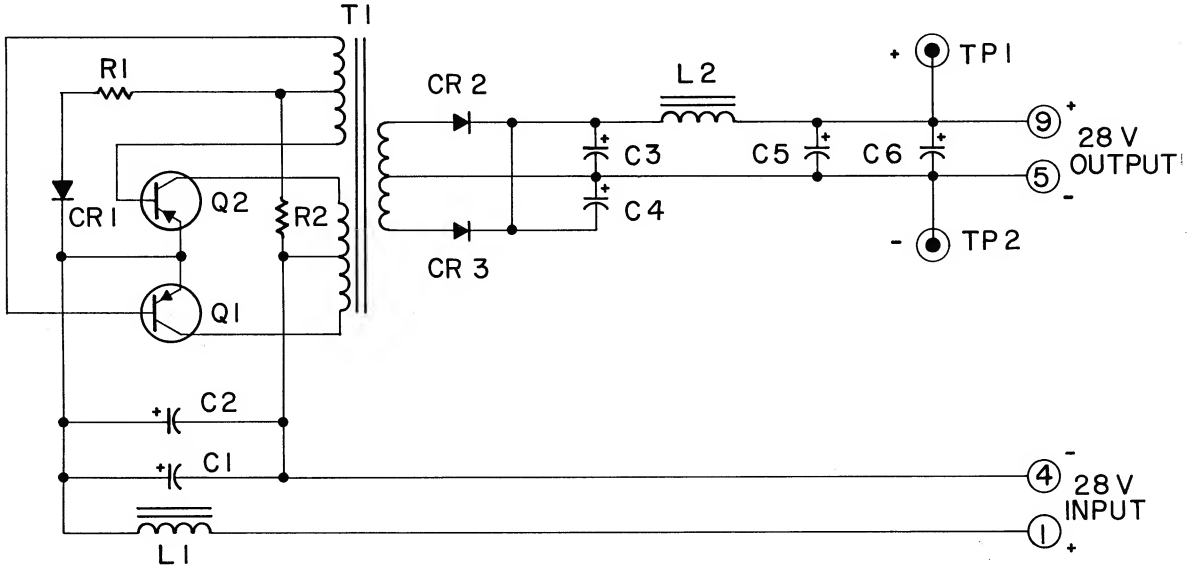
4/63




MODEL NO. **IR 402**

MATING CONNECTOR (NOT FURNISHED)
CANNON DE-9S.

DIMENSIONS NOMINAL UNLESS OTHERWISE SPECIFIED.



## LEACH MODEL TU-103 (OPTIONAL UNITS TU-105 AND TU-106) MONITOR SELECTOR UNIT

The Monitor Selector Unit is used to switch to selected magnetic heads and monitor the record current and reproduce voltage. The unit is used in bench testing the system and is not required for normal operation.

### ELECTRICAL SPECIFICATIONS:

| | |
|---|---|
| Switch Positions: | 14 |
| Switch Decks: | 3 |
| Reproduce Head Voltage Monitor: | The output voltage from any head may be monitored. |
| Record Head Current Monitor: | The input voltage across a 10 ohm resistor may be monitored for any head. |

Special Options not provided in TU-103:

1. Switches to operate all controls in the relay control box (start-stop, forward-reverse, power on-off)
2. Reduced number of test points (7 instead of 14 record current monitors, 0 or 7 reproduce head voltage monitors)
3. Input power terminals
4. Cables to the system

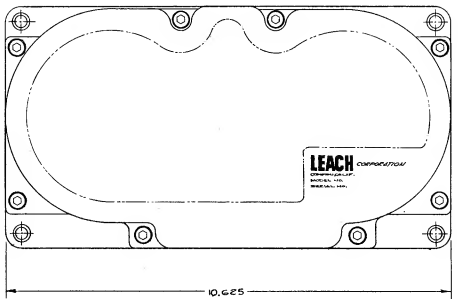
### MECHANICAL SPECIFICATIONS:

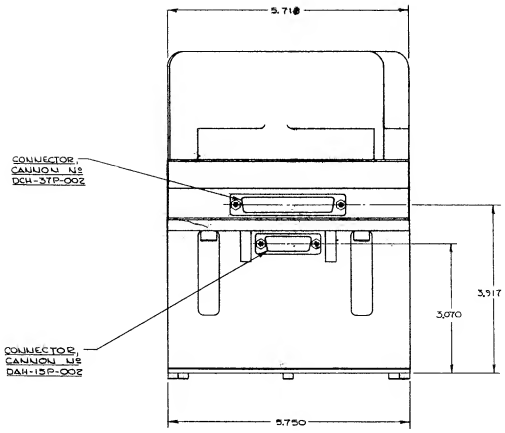
| | |
|---|---|
| Size: | Typical size 7 1/8"x 5 1/8"x 3 3/4" |
| Weight: | 2 lbs. approx. |
| Electrical Connector: | DC 37 |
| Part Number System: | Basic Number<br>TU 103 |

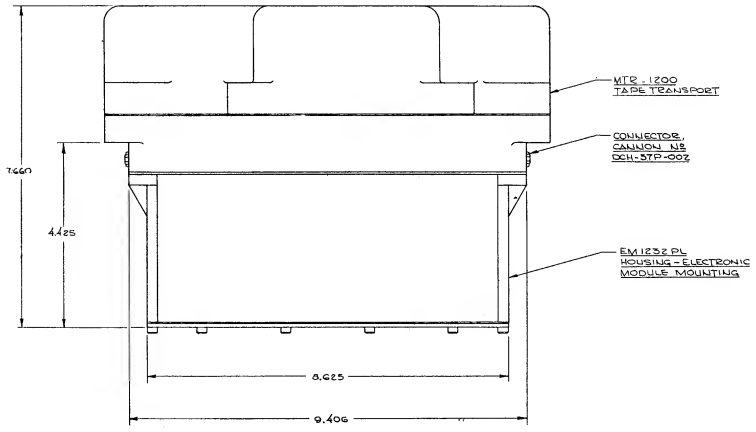
Satisfactory for field and laboratory use only.

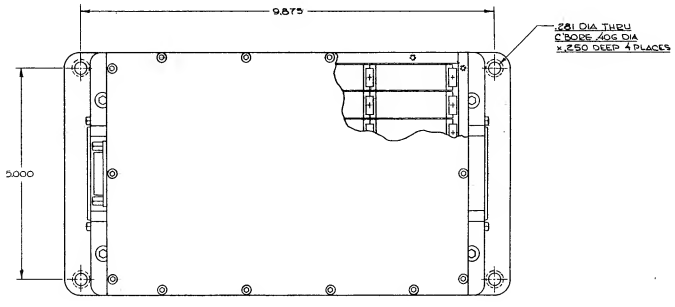
## ELECTRONICS HOUSING, 32 MODULES

The electronics module housing for high environment electronics is designed to mate directly with the MTR-1200 and hold up to 32 single modules. A complete recording system, containing up to 16 record amplifiers, power supplies, and associated motor drive and control logic circuits can be packaged into the module housing. Weight of the housing is 7.5 lbs.

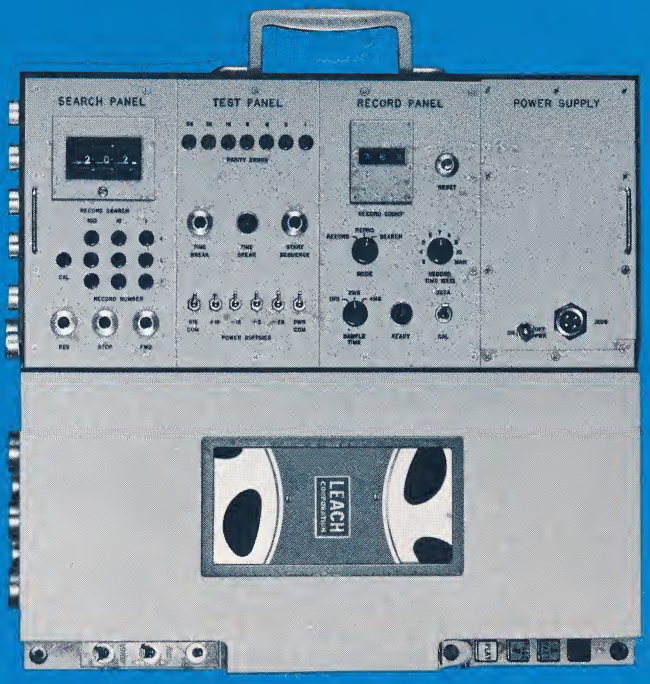

LEACH corporation
10.625


5.718
CONNECTOR, CANNON NS DCH-37P-002
CONNECTOR, CANNON NS DAH-15P-002
3.917
3.070
5.750


MTR - 1200 TAPE TRANSPORT
CONNECTOR, CANNON NS DCH-37P-002
EM 1232 PL HOUSING - ELECTRONIC MODULE MOUNTING
7.660
4.425
8.625
9.406


9.875
.281 DIA THRU C'BORE .406 DIA x.250 DEEP 4 PLACES
5.000

# LEACH CORPORATION
## CONTROLS DIVISION




**LEACH** DIGITAL DATA RECORDING SYSTEM DDR-3200

**The Leach Digital Data Recording System, developed specifically for seismic exploration data acquisition, is ready to deliver the accurate performance you require in your field operations.** ☐ Specialists in custom development of the smallest, most efficient magnetic tape recording and digital equipment for high environmental aerospace applications, Leach Controls Division engineers have applied their proven capabilities to develop the most compact system available to your industry—with the lowest power requirements—and simple to operate and maintain.

## A COMPLETE DATA ACQUISITION SYSTEM

The Leach DDR-3200 quantitizes, encodes and records analog signals and automatically converts them into a digital format on tape for later use on your computer system. Simultaneously, and as the digital signal is recorded, the data is reproduced in analog form for immediate readout on standard geophysical oscillographs. This complete 32-channel digital recording and "quick look" reproduction system combines the performance-tested Leach MTR-3200 instrumentation quality tape recorder/reproducer with an advanced PCM electronic section incorporating integrated circuit logic.

Four basic models, compatible with existing computer formats are available, and flexibility of design will permit modification for newly developed computers or changing field requirements.

| Leach Model | Computer Format |
|---|---|
| DDR-3207 | IBM 7-track |
| DDR-3207G | IBM 7-track gapped |
| DDR-3209 | IBM 9-track |
| DDR-3221 | CDC 21-track |

## SYSTEM OPERATION

The Leach DDR System utilizes advanced digital techniques yielding a short term accuracy of 0.01%. Provision is made for acceptance of 31 channels of analog input with a full scale range of ±2.0 to ±10.0 volts peak to peak.

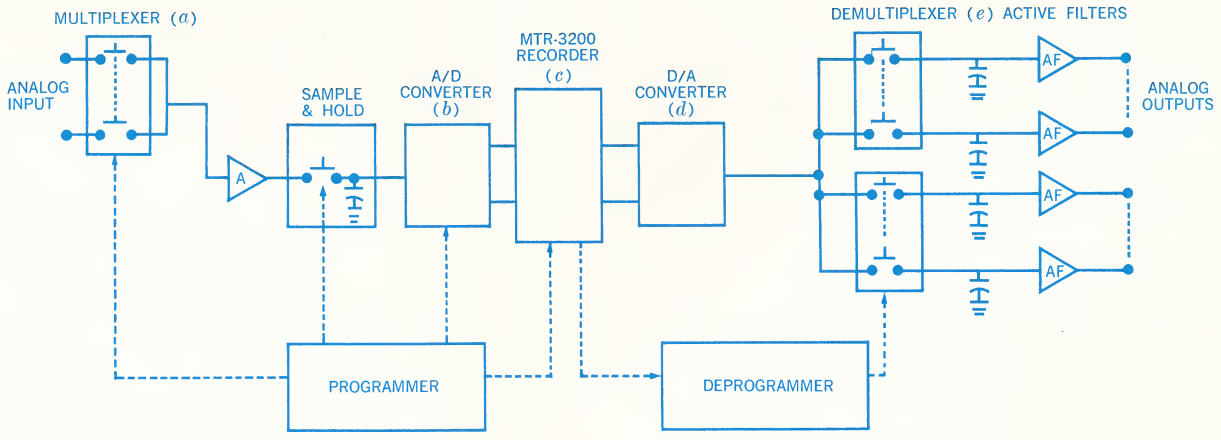
(a) **Multiplexer** — samples 31 input signals on a time-sharing basis at a rate of 1,000, 500, or 250 samples per channel per second as selected by the operator.

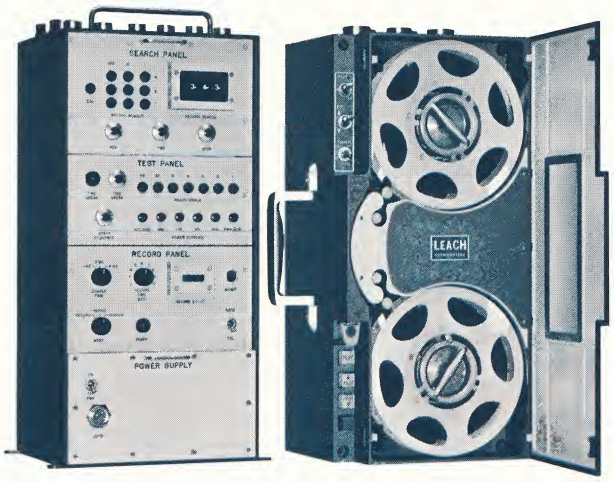
(b) **Analog to Digital Converter** — translates data into a 14 bit binary code.

(c) **Recorder** — stores binary data on ½ or 1 inch tape as required.

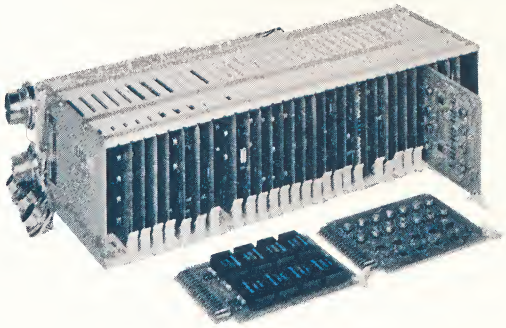
(d) **Digital-to-Analog Converter** — reads digital data from the tape and translates it into analog format.

(e) **Demultiplexer** — distributes reconstituted analog sample to proper analog output circuits.






*Efficiently packaged as one connected unit or in two sections (as shown)*



*Integrated circuits in functional two dimensional layout*

## OUTSTANDING OPERATIONAL FEATURES

**Playback Monitor** — The Leach system provides for continuous analog output signals derived from the digital tape. Analog reproduction of the digital recording is available to the observer as it is being recorded or, at any other time, through search and playback. A parity error counter provides a second effective monitor of digital record quality.

**File Protection** — During search or playback, record heads are deenergized; therefore, there is little chance of damage to original recorded data.

**Flexible Recording Sequence** — The system may be programmed to generate firing command or to synchronize with commands from the shot point. Radio or wire link with the shot point may be employed.

**Easy to Operate, Calibrate and Maintain** — Simplicity of operation allows the operator to concentrate his efforts on overall record quality. Tape reloading is a minor threading operation requiring less than one minute. Recording heads are easily accessible for cleaning. Automatically advanced record identification and parity error counter and display are provided. The PCM section, using integrated circuits in functional two dimensional layout, is designed to permit easy access for operating modifications.

**Compact, Versatile ▪ Plus Minimum Power Input** — By truck, helicopter, or hand-carried, the DDR-3200 is the most convenient-sized complete system available for field operational use. It is efficiently packaged as one connected unit or, since all connections are by external cables, in two sections which can be mounted independently. It's easily transported to any exploration site and operates at peak efficiency with minimum power input. A 12-volt power supply provides primary power to both the recorder and digital electronics sections of the system.

## PEAK PERFORMANCE UNDER ENVIRONMENTAL EXTREMES

Wherever your seismic exploration activities — marsh, desert, or marine — and whatever equipment transportation is provided — truck, helicopter or even hand-carried — the Leach DDR System withstands environmental stresses without performance degradation.

| | |
|---|---|
| Shock: | 25g - 8ms, ½ sine |
| Vibration: | 10g - 5 cps to 2 kc |
| Temperature: | 0°C to +71°C standard<br>−40°C to +71°C optional |
| Humidity: | 95% operating<br>100% non-operating |
| Sand & Dust: | Complete gasketing allows operation in heavy sand and dust atmosphere. |

## PHYSICAL CHARACTERISTICS

**Recorder Section**

Size: 8.625 x 9.5 x 20 inches
Volume: 0.95 cubic feet
Weight: 50 pounds

**PCM Electronics Section**

Size: 8.625 x 9.5 x 20 inches
Volume: 0.95 cubic feet
Weight: 40 pounds

**Primary Power Supply**

Source: 12 volt storage battery
Combined Power: 150 watts

# SPECIFICATIONS FOR DIRECT DIGITAL DATA ACQUISITION SYSTEM

## ANALOG INPUT

*Number of Channels*.....31 simultaneous data inputs plus frame synchronizing channel.

*Input Signal Level*.....All channels simultaneously adjust to accept signals within the range of ±2.0 to ±10.0 volts peak-to-peak.

*Input Impedance*.....1.0 megohm minimum shunted by less than 100 picofarads capacity (½ microamp maximum offset current).

*Over Ranging* .....Over-range signals encoded to full scale up to ±20 volts peak-to-peak.

*Over Range Recover*.....Recovery time from over-range transient voltages less than 32 microseconds.

*Aperture* .....Sample and hold aperture time less than 0.3 microseconds.

## SAMPLE RATES

*Primary Commutator Rate*.....1000, 500, 250 samples per second per channel, selectable.

*Timing Accuracy* .....Timing control derived from crystal clock within 0.01% accuracy.

## SYSTEM RECORD ACCURACY

*Coding Linearity* .....Within ½ least significant bit (encoded to fourteen bits, plus and minus ½ least significant bit).

*System Linearity* .....±0.01% ±½ least significant bit of full scale input voltage.

*Absolute System Accuracy* .....0.2% of full scale input voltage, long term, and inter-channel.

*Signal-to-Noise*.....84 db (peak-to-peak to rms) 72 db (peak-to-peak to peak-to-peak).

*Cross-talk* .....Inter-channel cross-talk less than 66 db with full range signals at input to all except measured channel.

*Bit Error* .....Less than 1 in $10^6$ bits under typical field operating conditions.

## DATA FORMAT

*Tape Width* .....0.5 inch or 1.0 inch as required.

*Recording Mode* .....Non-Return-to-Zero Mark (NRZI).

*Record Identification*.....Three digit octal file number recorded as pre-data identification word.

*Tape Formats* .....Standard 7, 9, and 21 track configurations.

*Parity* .....Vertical parity standard, LRC and CRC characters optional.

## ANALOG OUTPUT

*Number of Channels*.....31 simultaneous data outputs.

*Clock Outputs* .....One channel, one hundred cycle square wave (first output transition coincident with time break and synchronous with recorded data).

*Output Signal Level*.....±1.0 volts full scale into 600 ohm resistive load.

*Source Impedance* .....50 ohms maximum.

*Output Filter Characteristics* .....Output minus 3 db at 300 cps, 100 cps cutoff frequency optional (minus 40 db at carrier frequency).

## SYSTEM REPRODUCE PERFORMANCE

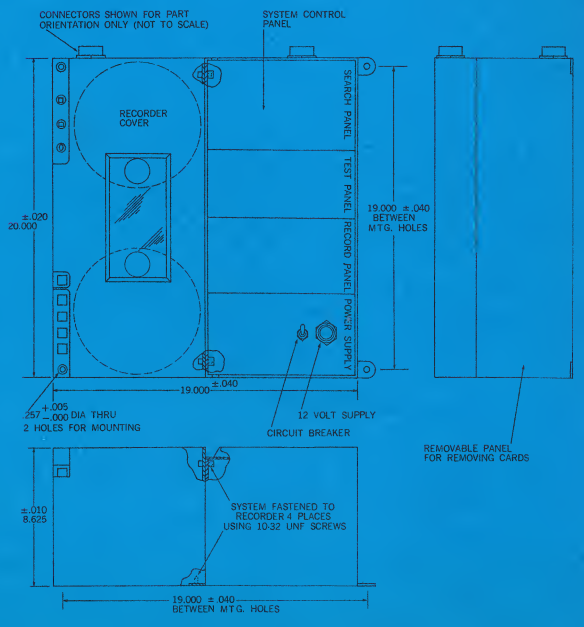
*Resolution* .....Digital-to-Analog conversion 9 most significant bits include sign bit.

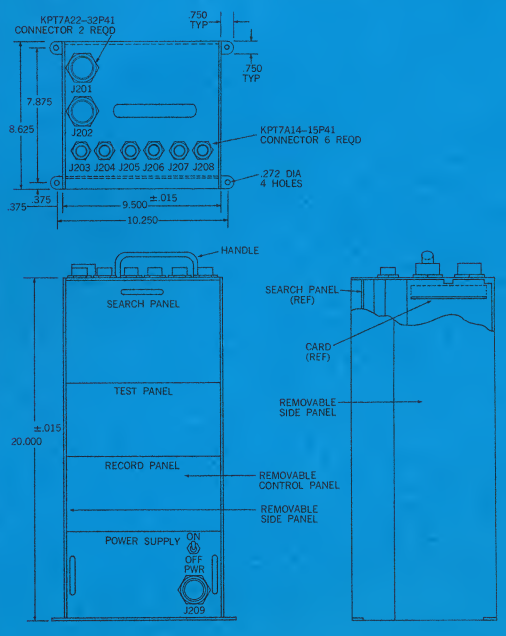
*Linearity* .....Within 0.2%.

## PROGRAMMING

*Firing Sequence* .....Start sequence and time break accepted from external source or start sequence and firing command may be generated internally.

*Record Length* .....Control programmable normally or in one second intervals from 3 to 10 seconds.





## COMPACT • PORTABLE • MINIMUM POWER REQUIREMENT

BY TRUCK, HELICOPTER OR HAND CARRIED, THE DDR-3200 IS THE MOST CONVENIENT-SIZED COMPLETE SYSTEM AVAILABLE FOR FIELD USE



# LEACH DIGITAL DATA RECORDING SYSTEM DDR-3200 DESIGNED, MANUFACTURED AND TESTED IN ONE OF AMERICA'S MOST MODERN ELECTRONIC FACILITIES



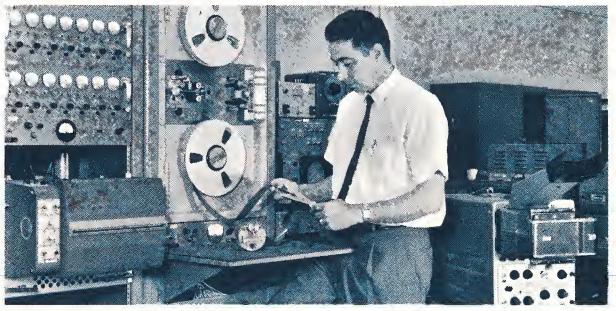
*Leach Controls Division Facility, Azusa, California*



*"White room" for the ultimate in contaminant-free assembly*



*Precision assembly area*



*Testing of Leach Tape Recorder on special ground playback equipment*

The Leach Controls Division is geared to undertake the development and production of custom-designed electronic systems and equipment. The all-new air conditioned plant at Azusa, California provides 61,000 sq. ft. of fully equipped engineering and manufacturing facilities.

Working in these ultra-modern facilities toward the development of increasingly sophisticated data acquisition equipment and systems is an experienced highly trained engineering staff. Their efforts are continually funnelled toward projects to meet the challenges created by space, geophysical and oceanographic exploration.

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For further information on Leach recording equipment to meet your specific application requirements, contact your nearest Leach District Sales Office or the main plant.

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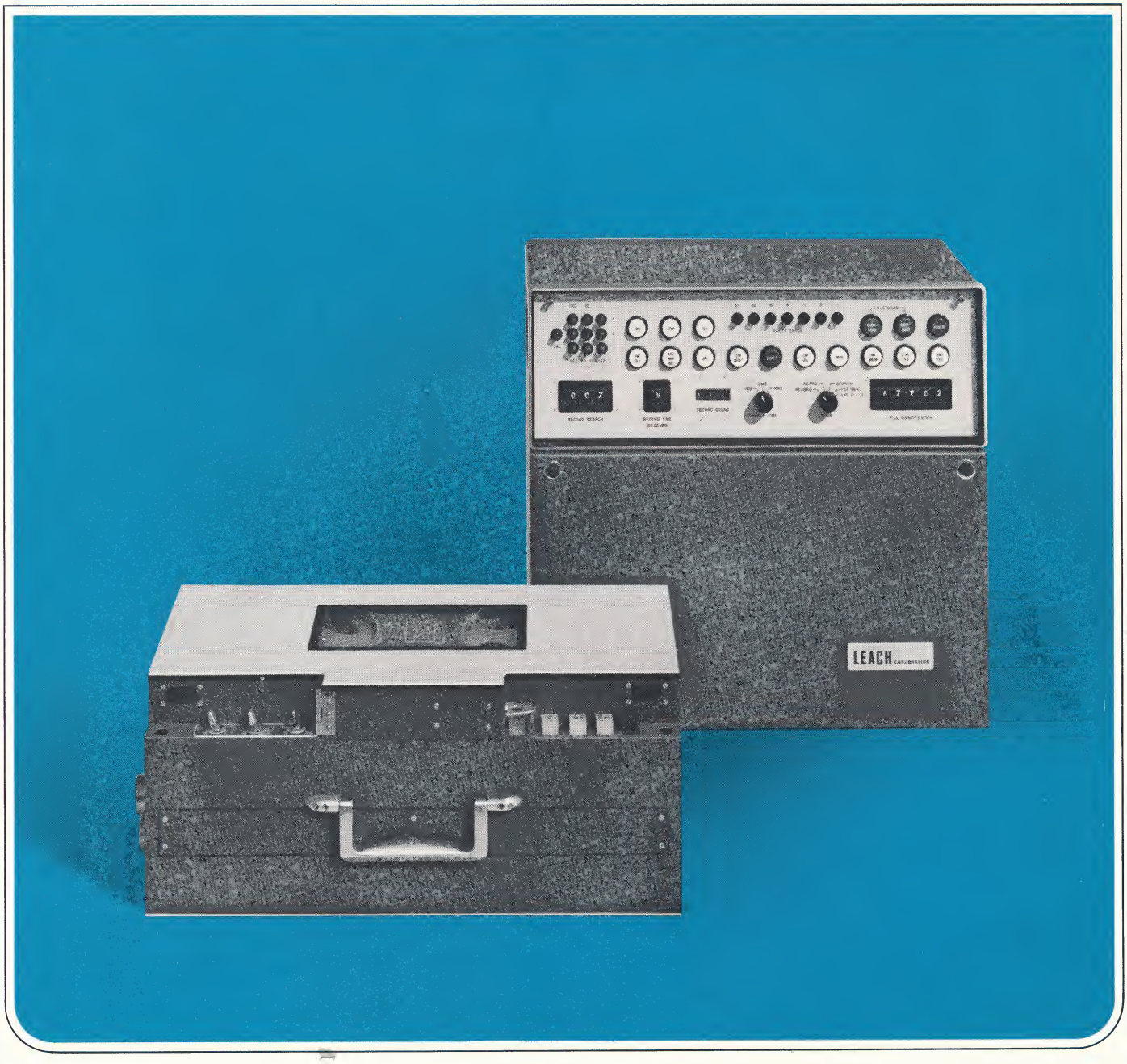
# LEACH CORPORATION

## CONTROLS DIVISION

DDR-3300

Direct Digital Recording System

Specifically designed for field environments



# Outstanding Operational Features

## Leach Series DDR-3300
## Direct Digital Recording System

Up to 40 input and output channels
0.01% system accuracy
Compatible with IBM 7 and 9 channel formats
Requires only 11 to 14 VDC input
Operates on less than 200 watts
Withstands 10g vibration, operating
Weighs less than 125 pounds, complete

### A Complete Data Acquisition System

The DDR-3300 is a portable digital recorder/reproducer providing the utmost in record quality, format efficiency and program flexibility. A complete data acquisition system, it quantitizes, encodes and records analog signals and converts them into a digital format compatible with IBM 7 and 9 track computers.

### Small Size, Light Weight, Low Power Consumption

Conveniently packaged in two lightweight sections (plus power supply) the DDR-3300 can be transported by truck, helicopter or even hand carried to arctic, desert, marsh or marine locations. An outstanding combination of small size and low power consumption is achieved by the use of silicon integrated circuits in all systems logic plus other advanced techniques.

### Easy To Operate, Calibrate And Maintain

Simplicity of operation allows the operator to concentrate his efforts on overall record quality. Tape reloading is a simple threading operation requiring less than one minute. Recording heads are easily accessible for cleaning. A parity error counter and analog reproduction of each data channel are provided as a monitor of record quality. The PCM section is easily accessible for maintenance and format or program changes.

### Peak Performance Under Environmental Extremes

Wherever your seismic exploration activities, and whatever equipment transportation is provided, the Leach DDR system withstands environmental stresses without performance degradation. It's tough enough to operate during 25g shock, 10g vibration, 0°C to 71°C temperature, and 95% humidity. Complete gasketing allows operation in heavy sand and dust atmospheres.

# Technical Specifications

## Maximum Flexibility in Program & Format Selection

### Analog Input

| | |
|---|---|
| Number of Channels | To 40 simultaneous data inputs (selectable). |
| Input Signal Level | All channels simultaneously adjustable to accept signals within the range of ± 2 volts peak-to-peak to ± 10 volts peak-to-peak. |
| Input Impedance | 1.0 megohm minimum shunted by less than 100 picofarads capacity (½ microamp maximum offset current). |
| Over-Ranging | Over-range signals encoded as full scale up to ± 20 volts peak-to-peak. |
| Over-Range Recover | Recovery from up to 100% over-range transient voltage less than 25 microseconds. |
| Aperture | Sample and hold aperture time less than 0.3 microseconds. |

### Sample Rates

| | |
|---|---|
| Primary Commutator Rate | 1000, 500, and 250 samples per second per channel, selectable. |
| Timing Accuracy | Timing control derived from crystal clock within .005% accuracy. |

### System Record Accuracy

| | |
|---|---|
| Coding Linearity | Within ½ least significant bit (encoded to fourteen bits, plus and minus ½ least significant bit). |
| System Linearity | ±0.01% ±½ least significant bit of full scale input voltage. |
| Absolute System Accuracy | 0.1% of full scale input voltage, long term, and inter-channel. |
| Cross-talk | Inter-channel cross-talk less than 66 db with full range signals at input to all except measured channel. |
| Noise | 84 db (peak-to-peak to rms).<br>72 db (peak-to-peak to peak-to-peak). |
| Bit Error | Less than 1 in $10^6$ bits under typical field operating conditions. |

### Data Format

| | |
|---|---|
| Tape Width | 0.5 inch. |
| Recording Mode | Non-Return-to-Zero Mark (NRZI) |
| Record Identification | Three digit octal record number recorded as pre-data identification word. |
| Tape Formats | Standard IBM 7 and IBM 9 formats. |
| Parity | Vertical and longitudinal parity standard, cyclic redundancy check character provided on 9 track format. |
| Digital Code | 13 binary bits plus sign, 1's complement for negative numbers (other codes also available). |

### Analog Output

| | |
|---|---|
| Number of Channels | To 40 simultaneous data outputs. |
| Clock Outputs | One channel, one hundred cycle square wave (first output transition coincident with time break and synchronous with recorded data). |
| Output Signal Level | ±1.0 volts full scale into 600 ohm resistive load. |
| Source Impedance | 50 ohms maximum. |
| Output Filter Characteristics | Output minus 3 db at 300 cps, 100 cps cutoff frequency optional (minus 40 db at carrier frequency). |

### System Reproduce Performance

| | |
|---|---|
| Resolution | Digital-to-Analog conversion 9 most significant bits including sign bit. Also 9 least significant bits are available through bit shift feature (see XI). |
| Linearity | Within 0.2%. |

### Programming

| | |
|---|---|
| Firing Sequence | Start sequence and time break accepted from external source or start sequence and firing command may be generated internally. |
| Record Length | 3 to 10 seconds in one second intervals. Manual record length control also provided. |

## Primary Power

| | |
|---|---|
| Input Voltage | 11 to 14 volts DC, reverse polarity protected. |
| Power | Less than 200 watts run.<br>Less than 150 watts standby. |
| Isolation | Separate signal, power and chassis grounds. |

## Physical Characteristics

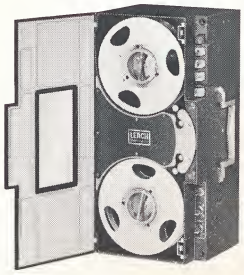
| | |
|---|---|
| Tape Recorder Unit | 8.6 x 9.5 x 20.0 inches, 55 pounds maximum weight. |
| PCM Electronics Unit | 20 x 19 x 10.37 inches, 50 pounds maximum weight. |
| Mounting | Digital and recorder units may be separated by 30 feet. |
| Power Supply | 20 x 10.37 x 6.0 inches, 25 pounds maximum weight. |

## Environmental Characteristics

| | |
|---|---|
| Temperature | 0° to +71°C, case temperatures (−20°C to +71°C optional). |
| Shock | 25g, 8 millisecond duration, any of three mutually perpendicular axis. |
| Vibration | 10g, 5 cps to 2000 cps. |
| Humidity | 95% operating, 100% non-operating. |
| Sand and Dust | All covers and connectors gasketed. |

## Special Features

| | |
|---|---|
| Format Conversion | Format conversion of digital electronics from IBM 9 to IBM 7 accomplished by plug-in card change only. Cards available for alternate formats under special orders. |
| Back-up Feature (optional) | The tape recorder is reversed at the end of each record for optimum tape utilization. |
| Bit Shift on Decoding Reproduce | Front panel switch selects 9 most significant bits or 9 least significant bits for reproduction (decoding 9 least significant bits effectively multiplies reproduce signals by 32). |
| Parity Error Counting | Parity error counter is provided to count total vertical parity errors per record. |
| Record Identification | Record number recorded at beginning of record. Automatically forwarded one digit with each start sequence command. |
| Reel Identification | Reel number, as set by front panel thumbwheel switch, recorded by operator command. |
| End-Of-File Marker | Unique word for end-of-file marker recorded upon operator command. |
| Record Number Display | The reproduce record number is displayed on control panel. |
| Record Search | Front panel thumbwheel switch allows automatic record search in forward or reverse direction. |
| Over Range Indicator | Front panel lamp indication when full scale input signal level is exceeded. |
| Test Points | Test points provided to isolate faults to individual card level — mechanical design provides ready access to all test points and components. |



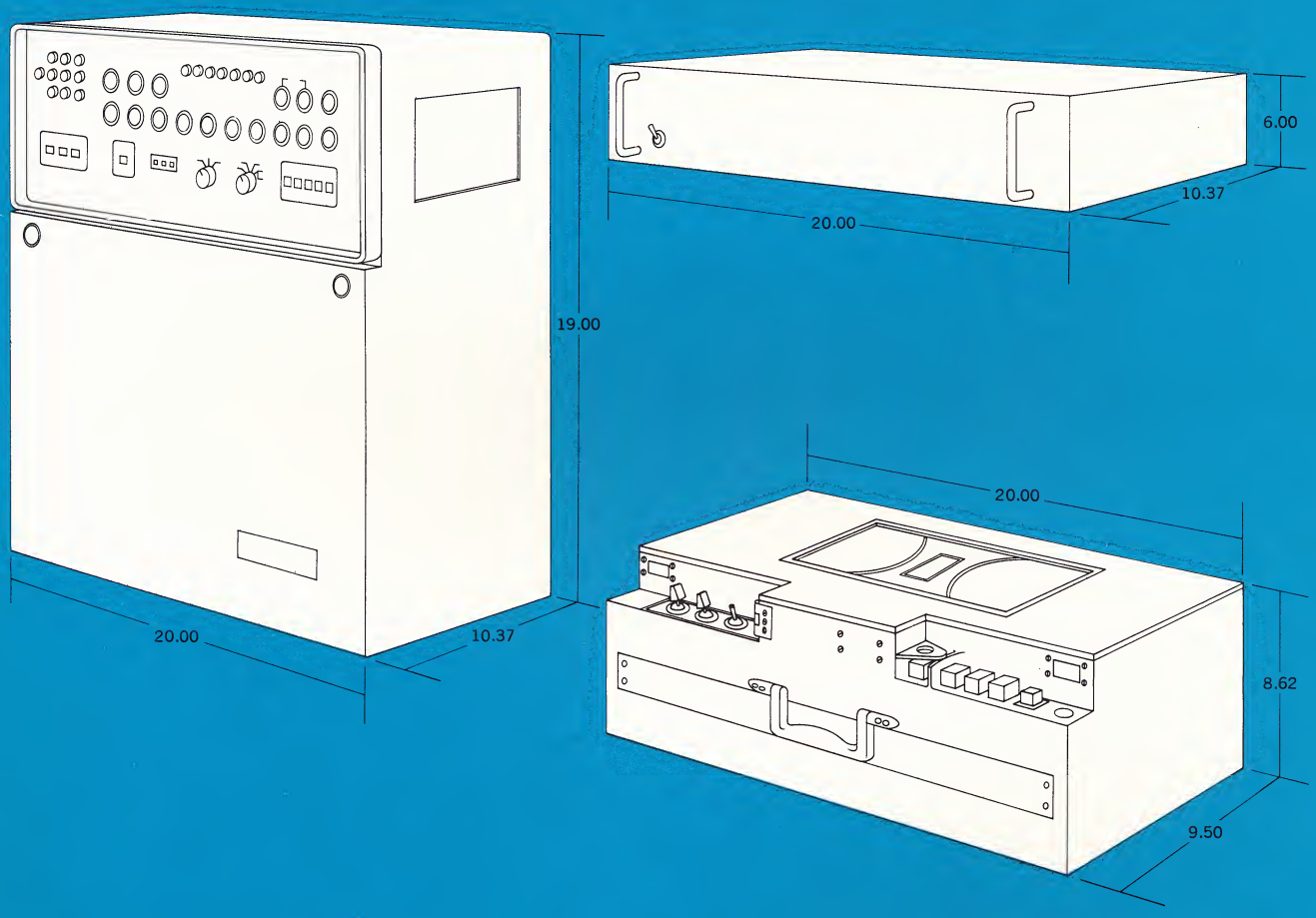
## Magnetic Tape Unit

*The magnetic tape section is a Leach MTR-3200 digital record/reproduce unit. Compact and lightweight, the MTR-3200 is easily hand carried in the field. Simplicity of design minimizes the chance of error. "Failsafe" push button controls are mounted on the front panel for operating ease.*

| | |
|---|---|
| Model | Leach MTR 3200 digital record reproduce unit. |
| Tape | ½" on 8" reels with IBM hubs, 3M will supply reels spooled with 1200 feet of IBM approved tape under their part number 8938-½-GR55C. Models using 1" tape also available. |
| Track Geometry | As specified for IBM series 2400 tape handling equipment or other industry standards. 21 track configuration also available. |
| Tape Speed | As required by system sampling rate, frame length and tape format up to maximum of 200 ips. |
| Packing Density | 800, 556 and 356 bpi as required. |

# Physical Dimensions

## Small Size, Lightweight



# Leach Direct Digital Recording System DDR-3300 designed, manufactured and tested in one of America's most modern Electronic Facilities



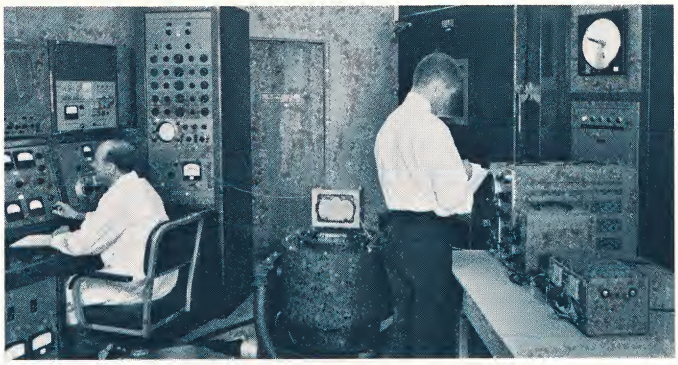
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*Precision assembly area*



*Testing of Leach Tape Recorder*

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Bulletin DDR-3300-1165

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# TAPE RECORDING TECHNIQUES

## 1.0 DATA RECORDING

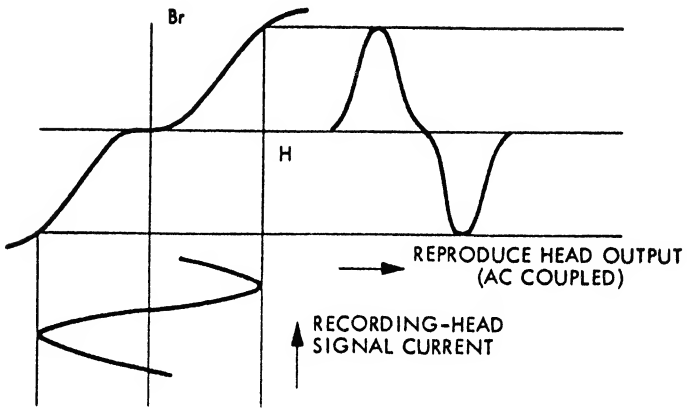
Data is commonly composed of many variable types of signals recorded by various techniques. These signals may be DC or AC, simple waveforms or complex, low frequency or high frequency, low level or high level, transient or continuous. One problem common to many instrumentation applications is the selection of the proper "data carrier" or "conversion equipment. It is well known that in many cases the data cannot be readily handled in the form in which it was originated. That is, the transducer output may be of too low a level for direct meter monitoring, or the data may have a frequency component which is too rapid for simple recording or it just may be that the environment will not allow the use of oscillographic or pen type recording.

In view of these and many other factors, we may find that the magnetic tape method of data recording is chosen as the desirable method. This method gives assured data storage with consistent and convenient reproduction at any time. It also permits more careful analysis of the data through such techniques as continuous repetition on a loop recorder for spectrum analysis and time base variations available by tape speed selection.

But how can data be recorded? What techniques are available, and where should they be used? Assuming the reader understands the basic electronic and mechanical principles of magnetic tape recording, we will review the various techniques and try to define where and when they can be successfully used.

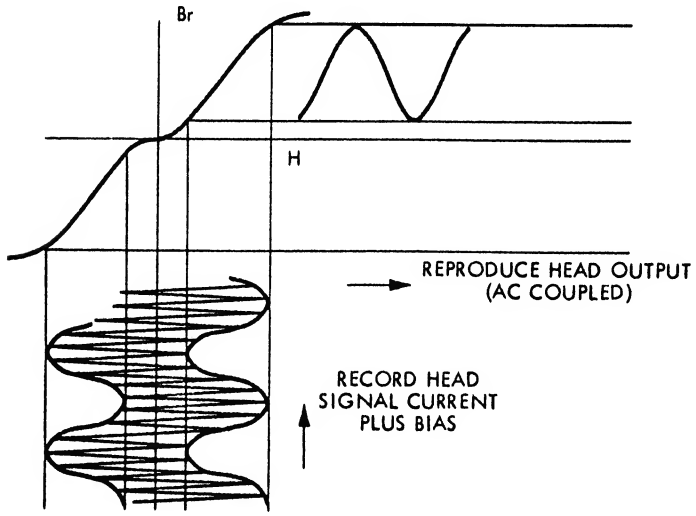
## 2.0 DIRECT OR ANALOG RECORDING

Of the many techniques available, the direct recording process is perhaps the most familiar since it is the technique commonly used for the recording of speech and music. This technique consists of amplifying the signal to be recorded to a suitable level and mixing it with a relatively high frequency AC bias. These combined frequencies are then presented directly to the recording head as a varying electrical current.




RECORDING WITHOUT BIAS

- REPRODUCE HEAD OUTPUT IS LARGE BUT DISTORTED
- THIS IS ACCEPTABLE TO PRESERVE TIME, FREQUENCY AND EVENTS
- THEREFORE, IT IS USED FOR DIGITAL - PDM - SOME SWITCH CLOSURES AND SOME FM




RECORDING WITH PROPER BIAS

- REPRODUCE HEAD OUTPUT IS SMALLER BUT IS CHARACTERISTIC OF THE RECORDER WAVE FORM WITHOUT BIAS
- THIS IS ACCEPTABLE TO PRESERVE CHARACTER OF ALL WAVE FORMS WITHIN THE FREQUENCY RANGE AS IT DEFINES AMPLITUDE FAIRLY WELL AT ANY POINT IN TIME
- HOWEVER, ACCURACY IS ONLY AS GOOD AS THE TAPE AND THE TAPE TO HEAD CONTACT UNIFORMITY

DIRECT RECORDING WITH BIAS

FIGURE 1

## 2.0 DIRECT OR ANALOG RECORDING (Continued)

Using special techniques to provide higher tape speeds relative to the record and reproduce heads, it has been possible to record into the megacycle range. In addition, direct recording can handle these frequencies over a reasonably wide dynamic range of input signals, including amplitudes beyond those normally anticipated without any extreme increase in distortion. The amplitude accuracy of direct recording can be estimated as between 5% and 10% with peak errors of relatively short duration approaching 15% of full scale.

When introducing the direct recording process, mention was made that the signal to be recorded was mixed with a high-frequency bias. This is done to essentially eliminate the nonlinear portion of the tape transfer curve in order to provide low distortion.

Since the amplitude of the bias signal is several times that of the recorded signal, it is important to note that combining of the bias and recorded signal, is accomplished by a linear mixing process, with no new sum and difference frequencies being introduced. This mixing is not an amplitude-modulation process, in which new frequencies would be introduced. A signal mixed with bias is presented as recorded in Figure 1.

The bias frequency does not otherwise enter into the recording process, or the subsequent playback process. The wave lengths, which would correspond to the high-frequency bias signal, would be too small to be resolved by the playback head. The actual value of the bias frequency is not too critical, and usually is made at least 3.5 times the highest frequency to be recorded, to minimize any interaction which might occur between the bias frequency and the higher-order harmonics of the recorded signal frequencies.

The construction of the record head used consists of a magnetic core in the form of a closed ring, having a short non-magnetic gap in series with the magnetic path of the core. As the tape moves across the head, the surface of the tape contacts the magnetic head at the gap, shunting the gap, and completing the magnetic path in the head core. The signal current flows through a winding surrounding the magnetic core and produces magnetic flux whose magnitude is proportional to the recording current. With the tape moving across the heads at a given tape speed, any particle of the magnetic medium crossing the gap remains in a permanent state of magnetization proportional to the flux flowing

## 2.0 DIRECT OR ANALOG RECORDING (Continued)

through the head at the instant that particle passes out of the gap. Thus, the actual recording takes place at the trailing edge of the record gap. If the signal to be recorded is sinusoidal, the intensity of magnetization on tape varies sinusoidally along the length of the tape. The wave length of the recorded signal is directly proportional to the tape speed and inversely proportional to the frequency of the input signal.

During playback the tape passes the gap of a reproduce head, similar in construction to the record head. The portion of tape in contact with the gap is bridged by the magnetic-core of the reproduce head so that the magnetic lines of flux flow through the core. The magnitude of this flux is a function of the average state of magnetization on that portion of the tape actually spanned by the gap at any given instant. As the tape passes the reproduce gap, the amount of flux through the core varies, causing a voltage to be generated in the winding linking the core. The voltage generated is not determined by the magnitude of the flux, but by its rate of change $\left(\frac{d\phi}{dt}\right)$.

Thus, if flux is proportional to the recording current, the playback voltage from the reproduce head is dependent upon the frequency. Because output is proportional to rate of change of flux, DC data cannot be reproduced with conventional reproduce heads. The practical lower frequency limit is approximately 50 cps. The high frequency end of the recording spectrum has a limitation fundamental to all recording processes. As mentioned previously, the average value of tape magnetization spanned by the gap is continually changing, resulting in an output voltage from the head. If a frequency high enough to have a wave length equal in length to the reproduce head gap should be recorded on the tape at a given speed,then the output from the reproduce head would be zero. This phenomena is due to the state of magnetization of this particular wave length being short enough to fall between the gap instead of bridging the gap. As the frequency approaches that value at which the wave length equals the gap length, the output from the reproduce head falls off rapidly. The frequency vs. output characteristics of a typical reproduce head is shown in Figure 2. It is not recommended, in practical applications, that over 75%, approximately, of a wave length be allowed to shunt the reproduce head gap. Although the limitation on high frequency response resulting from this gap-effect cannot be eliminated, it can be improved by either reducing the size of the reproduce head gap or by increasing the tape speed. In reducing the gap size to get better resolution of high frequencies, the output level falls causing deterioration of dynamic range or signal-to-noise ratio.

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RELATIVE REPRODUCE HEAD OUTPUT FOR STANDARD TAPE SPEEDS

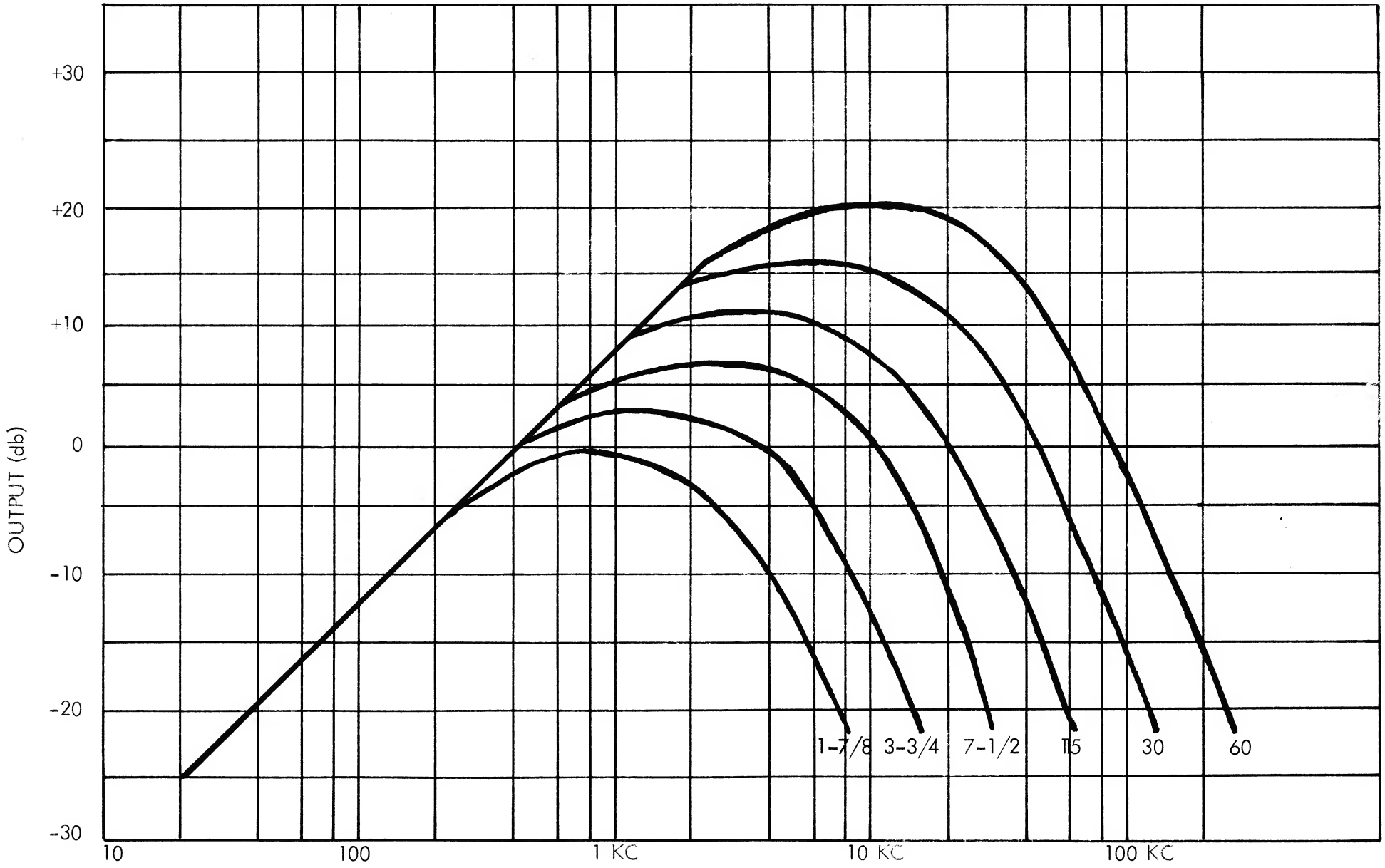



FIGURE 2

666-71

## 2.0 DIRECT OR ANALOG RECORDING (Continued)

The frequency response of the direct recording process, using presently available and standard techniques, is limited on the low end to about 50 cycles at relatively low tape speeds. On the high end of the spectrum at 60 inches per second, the limit is about 1 mc. This is a rather new limit and 250 kc is probably a more familiar number.

When this technique is used with music, it is quite suitable due to the inability of the ear to respond to minute flaws in recording or to be able to detect very low frequencies. Instrumentation data recording demands more accurate analysis.

One of the primary limitations of the direct recording technique is the problem sometimes referred to as amplitude instability. This effect is caused primarily by the magnetic non-uniformity of the recording media and by flecks of foreign material such as dust. Poor quality tape also contains "nodules" which are clusters of oxide particles on the surface of the tape. The effect of the magnetic non-uniformity is a low-level modulation which in some cases may approach 13% or approximately 2 db at the 1% distortion level. The nodules and foreign matter such as dust create drop-outs which are short duration losses of data. This is caused by the tape being lifted away from the heads. This drop-out effect, when recording audio, is relatively unimportant, but in instrumentation recording this effect might occur at the instant when some transient phenomenon occurs and result in loss of data.

Another one of the problems with direct recording, as applied to instrumentation, is the signal-to-noise ratio. With a record current level selected for a 1% distortion of the third harmonic (normal full-scale record level), the S/N ratio will be 35 db, or the noise level will be 2% of the full-scale signal level. This is not the maximum signal level that can be recorded but merely the 1% distortion point. If 3% distortion can be tolerated then the S/N ratio will be 40 db or 1% of the full scale. This noise is inherent in tape recording due to the magnetic properties of the recording media and the low signal from the reproduce heads. This is wideband noise equal to normal frequency bandwidth for a given tape speed.

Direct recording does have the distinct advantage of providing the widest possible frequency range for any given tape speed. Using standard tape speeds from 1-7/8 ips to 60 ips, the frequency spectrum covers the ranges from 50 cps to 1 mc.

## 2.0 DIRECT OR ANALOG RECORDING (Continued)

In practical applications, direct record channels will yield the frequency response related to the tape speed and gap length as tabulated below:

| | Gap Length | | |
|---|---|---|---|
| Tape Speed | 250 Micro Inches | 100 Micro Inches | 40 Micro Inches |
| 120 | 200 KC | 500 KC | 1 MC |
| 60 | 100 KC | 250 KC | 500 KC |
| 30 | 50 KC | 125 KC | 250 KC |
| 15 | 25 KC | 62.5 KC | 125 KC |
| 7.5 | 12.5 KC | 31.25 KC | 62.5 KC |
| 3-3/4 | 6.25 KC | 15.625 KC | 31.25 KC |
| 1-7/8 | 3.125 KC | 7.812 KC | 15.625 KC |
| 15/16 | 1.562 KC | 3.906 KC | 7.812 KC |

To obtain a flat frequency response over the bandwidths indicated above, the reproduce amplifier must have a frequency response characteristic that is the inverse of the reproduce head characteristic. This is referred to as "playback" equalization. A different equalization network is required for each tape speed and gap length.

### Direct Recording Applications

Spectrum analysis: In many cases, the data desired is primarily frequency rather than amplitude. Such cases would include vibration spectrum studies as well as noise measurement. For data of this type, the direct record process is suitable.

Timing Reference and Voice Monitor: The recording of a time base for accurate tape speed correlation is conveniently handled by this technique. It is also desirable, at times, to provide a voice commentary describing events, relationships between them, etc. Both the reference data and this voice information can be recorded on the same track, if necessary.

## 2.0 DIRECT OR ANALOG RECORDING (Continued)

Data Multiplexing: By utilizing the multiplexed FM technique (described later) several channels of information can be recorded on a single track using direct recording with high frequency AC bias. The wide frequency spectrum that can be recorded permits using up to 18 IRIG channels for input to a single track on tape at a tape speed of 60 ips.

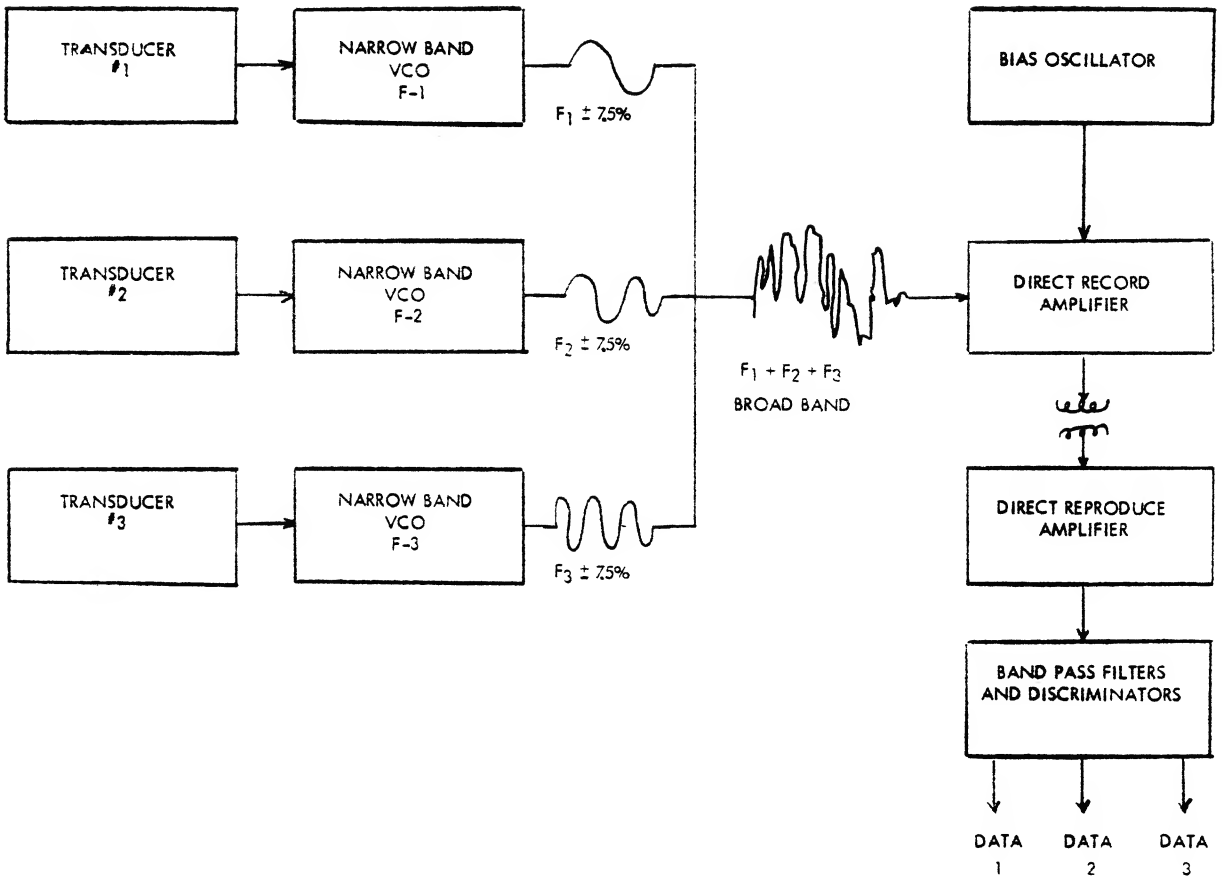
## 3.0 FREQUENCY MODULATION RECORDING (FM)

The frequency modulation recording technique was developed in order to overcome the two basic limitations of the direct recording process, namely, the inability to record very low frequencies or DC and the amplitude instability caused by tape drop-outs. This method employs a carrier frequency, which is frequency modulated by the intelligence to be recorded. A center frequency is selected, determined by the tape speed desired, which corresponds to a zero input signal. A DC signal of positive polarity shifts the carrier frequency a given percentage in one direction. A DC signal of negative polarity shifts the carrier an equal percentage in the opposite direction. An AC input signal shifts the carrier alternately on both sides of the center frequency, at a rate equal to the frequency of the input signal. All information presented to the tape, in this manner, is preserved in the frequency domain and normal amplitude instabilities have little or no effect on the intelligence recorded.

### 3.1 Narrow-Band FM

The first applications of FM recording techniques were employed in frequency-division multiplexing where a number of individual carrier frequencies (each individual one employing a different center frequency) are each modulated by a separate input signal.

A complex of many subcarrier frequencies, resulting from the multiplexing process, is then mixed linearly and the composite signal is recorded using the direct recording method. The combination of the wide analog bandwidth and linearity characteristics of the direct recording method permits the simultaneous recording of many discrete subcarrier frequencies on one track of tape without introducing objectionable intermodulation distortion.




MULTIPLEXED FM RECORDING

FIGURE 3

**ADVANTAGES**

- UP TO 18 CHANNELS/TRACK
- READY AVAILABILITY OF DEMODULATION EQUIPMENT
- FREQUENCY RESPONSE EXTENDS DOWN TO DC

**DISADVANTAGES**

- AMPLITUDE ACCURACY IS VERY DEPENDENT ON TAPE SPEED, 1% P/P FLUTTER CAUSES 6.6% P/P AMPLITUDE ERROR
- UPPER FREQUENCY RESPONSE IS LIMITED BY BOTH MODULATION INDEX AND FREQUENCY GUARD BANDS SO THAT 4 DATA CYCLES OCCUPY APPROXIMATELY THE SAME TAPE LENGTH AS 100 DIRECT RECORDED CYCLES

3.1 Narrow-Band FM (Continued)

In order to record a multiplicity of carriers in the available frequency spectrum, it is necessary to restrict the maximum frequency deviation of any one carrier. The frequency deviation commonly used on each subcarrier is ±7.5% of center frequency. ±15% is also used on some of the higher bands when extension of the data upper frequency response is required. IRIG standard subcarrier bands are tabulated on the following page.

Because the intelligence in an FM system is indicated by changes in frequency, the tape transport must move the tape across both the record and reproduce heads at a very precise and consistent speed. Any variations in the tape speed will appear as frequency changes and consequently will simulate data. The result is inaccuracy. Tape speed variations, therefore, become one of the primary factors in the accuracy of an FM system. These speed variations are particularly detrimental in the frequency multiplex system described above. When one considers that a 15% p/p deviation (±7.5%) corresponds to a 100% input signal, a 1% p/p deviation in frequency resulting from FLUTTER in the transport, would appear as 1/15 or a 6.6% noise signal. This noise signal, due to changes in tape speed, can be reduced by 50 to 1 using wow and flutter compensation techniques that will be described later.

## FM/FM TELEMETRY SUBCARRIER BANDS

| Channel | Center Frequency (cps) | Deviation (cps) | Lower Limit (cps) | Upper Limit (cps) | Data Frequency (Modulation Index 5) (cps) |
|---|---|---|---|---|---|
| 1 | 400 | ±30 | 370 | 430 | 6.0 |
| 2 | 560 | 42 | 518 | 602 | 8.4 |
| 3 | 730 | 55 | 675 | 785 | 11 |
| 4 | 960 | 72 | 888 | 1,032 | 14 |
| 5 | 1.3 KC | 98 | 1,202 | 1,398 | 20 |
| 6 | 1.7 | 128 | 1,572 | 1,828 | 25 |
| 7 | 2.3 | 173 | 2,127 | 2,473 | 35 |
| 8 | 3.0 | 225 | 2,775 | 3,225 | 45 |
| 9 | 3.9 | 293 | 3,607 | 4,193 | 59 |
| 10 | 5.4 | 405 | 4,995 | 5,805 | 81 |
| 11 | 7.3 | 551 | 6,799 | 7,901 | 110 |
| 12 | 10.5 | 788 | 9,712 | 11,288 | 160 |
| 13 | 14.5 | 1,088 | 13,412 | 15,588 | 220 |
| 14 | 22.0 | 1,650 | 20,350 | 23,650 | 330 |
| 15 | 30.0 | 2,250 | 27,750 | 32,250 | 450 |
| 16 | 40.0 | 3,000 | 37,000 | 43,000 | 600 |
| 17 | 52.5 | 3,940 | 48,560 | 56,440 | 790 |
| 18 | 70.0 | 5,250 | 64,750 | 75,250 | 1,050 |
| 19 | 93.0 | 6,975 | 86,025 | 99,975 | 1,400 |
| 20 | 124.0 | 9,300 | 114,700 | | 1,900 |
| 21 | 165.0 | 12,375 | 152,625 | 177,375 | 2,500 |
| | | ±15% DEVIATION CHANNELS* | | | |
| A | 22.0 | 3,800 | 18,700 | 25,800 | 660 |
| B | 30.0 | 4,500 | 25,500 | 34,500 | 900 |
| C | 40.0 | 6,000 | 34,000 | 46,000 | 1,200 |
| D | 52.5 | 7,880 | 44,620 | 60,380 | 1,600 |
| E | 70.0 | 10,500 | 59,500 | 80,500 | 2,100 |
| F | 93.0 | 13,950 | 79,050 | 106,950 | 2,800 |
| G | 124.0 | 18,600 | 105,400 | 142,600 | 3,700 |
| H | 165.0 | 24,750 | 140,250 | 189,750 | 5,000 |

*When using wide bands, adjacent bands must be omitted as follows:

| When Using Band | Omit Bands |
|---|---|
| A | 15 and B |
| B | 14, 16, A and C |
| C | 15, 17, B and D |
| D | 16, 18, C and E |
| E | 17, 19, D and F |
| F | 18, 20, E and G |
| G | 19, 21, F and H |
| H | 20 and G |

### 3.1.1 Constant Bandwidth FM

A number of severe limitations in the standard IRIG narrow band FM system, notably information frequency response and efficient bandwidth utilization, have led to the development of the constant bandwidth FM subcarrier system. The subcarriers all have the same deviation frequency, regardless of center frequency, rather than the same percentage deviation. This gives all channels the same information bandwidth.

The following table gives the constant bandwidth channels established for IRIG. Many variations are possible and available to fit a given data system. Various modulation indexes may be used with the constant bandwidth scheme; data frequency bandwidths with $m = 2$ and $m = 5$ are tabulated.

The EMR standard constant bandwidth channels are also tabulated. The EMR system is in wider use than the IRIG proposed system and may supplant IRIG.

Tape speed accuracy and flutter are even more important in the constant bandwidth system. Percent deviation of the higher frequency carriers is less than 2%, so that 0.2% flutter represents 10% error. The same flutter is only 2.5% error in the narrow band system.

# PROPOSED IRIG STANDARD
# CONSTANT BANDWIDTH FM SUBCARRIER CHANNELS

| Band | Center Frequency (KC) | Deviation (KC) | Frequency Response (cps) m = 2 | m = 5 |
|---|---|---|---|---|
| 1C | 12.5 | ± 2 | 1000 | 400 |
| 2C | 20.8 | " | 1000 | 400 |
| 3C | 29.2 | " | 1000 | 400 |
| 4C | 37.5 | " | 1000 | 400 |
| 5C | 45.8 | " | 1000 | 400 |
| 6C | 54.2 | " | 1000 | 400 |
| 7C | 62.5 | " | 1000 | 400 |
| 8C | 70.8 | " | 1000 | 400 |
| 9C | 79.2 | " | 1000 | 400 |
| 10C | 87.5 | " | 1000 | 400 |
| 11C | 95.8 | " | 1000 | 400 |
| 12C | 104.2 | " | 1000 | 400 |
| 13C | 112.5 | " | 1000 | 400 |
| 14C | 120.8 | " | 1000 | 400 |
| 15C | 129.2 | " | 1000 | 400 |
| 16C | 137.5 | " | 1000 | 400 |
| 17C | 145.8 | " | 1000 | 400 |
| 18C | 154.2 | " | 1000 | 400 |
| 19C | 162.5 | " | 1000 | 400 |
| 20C | 170.8 | " | 1000 | 400 |
| 21C | 179.2 | " | 1000 | 400 |
| 22C | 187.5 | " | 1000 | 400 |
| 2CW | 20.8 | ± 4 | 2000 | 800 |
| 4CW | 37.5 | " | 2000 | 800 |
| 6CW | 54.2 | " | 2000 | 800 |
| 8CW | 70.8 | " | 2000 | 800 |
| 10CW | 87.5 | " | 2000 | 800 |
| 12CW | 104.2 | " | 2000 | 800 |
| 14CW | 120.8 | " | 2000 | 800 |
| 16CW | 137.5 | " | 2000 | 800 |
| 18CW | 154.2 | " | 2000 | 800 |
| 20CW | 170.8 | " | 2000 | 800 |
| 22CW | 187.5 | " | 2000 | 800 |

## STANDARD EMR 21-CHANNEL SYSTEM

## CONSTANT BANDWIDTH FM SUBCARRIER CHANNELS

| Channel | Group | Center Freq. (kc) ±1 kc System | Center Freq. (kc) ±2 kc System | Center Freq. (kc) ±4 kc System | Center Freq. (kc) ±8 kc System |
|---|---|---|---|---|---|
| 0 | A | 4 | 8 | 16 | 32 |
| 1 | A | 8 | 16 | 32 | 64 |
| 2 | A | 12 | 24 | 48 | 96 |
| 3 | A | 16 | 32 | 64 | 128 |
| 4 | A | 20 | 40 | 80 | 160 |
| 5 | A | 24 | 48 | 96 | 192 |
| 6 | A | 28 | 56 | 112 | 224 |
| 7 | B | 32 | 64 | 128 | 256 |
| 8 | B | 36 | 72 | 144 | 288 |
| 9 | B | 40 | 80 | 160 | 320 |
| 10 | B | 44 | 88 | 176 | 352 |
| 11 | B | 48 | 96 | 192 | 384 |
| 12 | C | 52 | 104 | 208 | 416 |
| 13 | C | 56 | 112 | 224 | 448 |
| 14 | C | 80 | 120 | 240 | 480 |
| 15 | C | 64 | 128 | 256 | 512 |
| 16 | C | 68 | 136 | 272 | 544 |
| 17 | D | 72 | 144 | 288 | 576 |
| 18 | D | 76 | 152 | 304 | 608 |
| 19 | D | 80 | 160 | 320 | 640 |
| 20 | D | 84 | 168 | 336 | 672 |
| 21 | D | 88 | 176 | 352 | 704 |
| Ref. | | 120 | 240 | 480 | 960 |
| Max. Data Freq. (MI = 2) | | 0.5 kc | 1.0 kc | 2.0 kc | 4.0 kc |

## 3.2 Wide Band ($\pm$ 40%) FM

The advantages of FM discussed above are offset somewhat by the limited upper frequency response of narrow band multiplexed FM. A wider frequency deviation coupled with a high center frequency significantly extends the data bandwidth and accuracy of an FM channel.

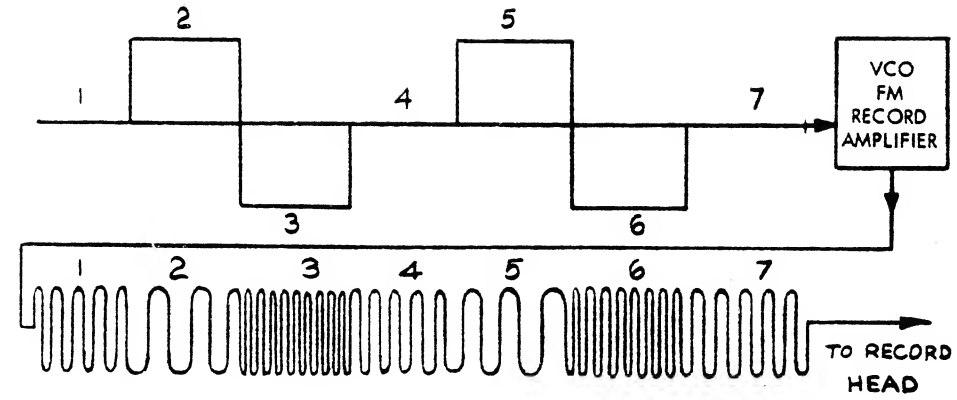
In practical application, the Wide Band FM recording technique will yield the frequency response related to the tape speed and carrier frequency as tabulated on the following page.

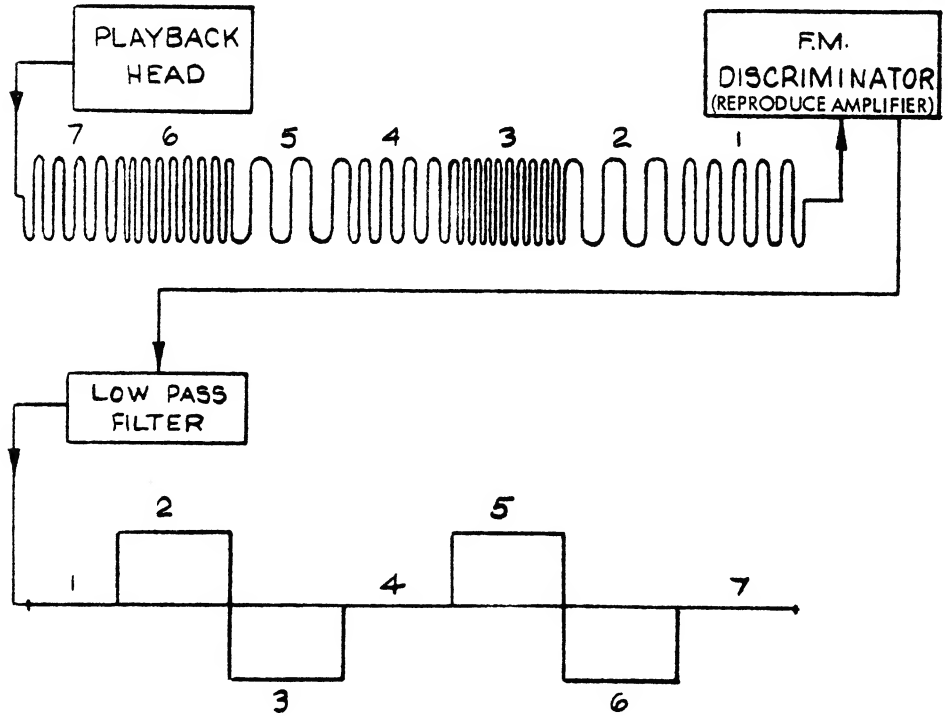
Figure #4 illustrates a basic FM record and reproduce system.

Considering the wide deviation only one carrier can be recorded on each track of tape as most of the bandwidth of the recorder is required for this signal. When one considers that all data information is contained in the frequency, the integrity of the carrier form need not be preserved. No bias is required and the carrier may be recorded to saturation.

The wide deviation offers distinct advantages by reducing data errors related to flutter. When p/p deviation is 80%, a 1% p/p flutter causes a $\frac{1}{80}$ or 1.25% error. This represents an improvement of better than 5:1 over the 6.6% related to narrow band FM.

LEACH CORPORATION




ADVANTAGES

- IMPROVED AMPLITUDE ACCURACY.
- FREQUENCY RESPONSE EXTENDS DOWN TO DC.
- MINIMUM PHASE DISTORTION ON PLAYBACK.

DISADVANTAGES

- AMPLITUDE VARIES PROPORTIONAL TO TAPE SPEED.
- UPPER FREQUENCY RESPONSE IS LIMITED TO 1/3 OR LESS OF THE MAXIMUM CARRIER WHICH CAN BE RECORDED.
- ONLY ONE DATA CHANNEL CAN BE RECORDED PER TRACK.

SINGLE CARRIER FM RECORD AND REPRODUCE

FIGURE 4

## SINGLE-CARRIER FM RECORD PARAMETERS

| Tape Speed (ips) | | | Carrier Center Frequency (cps) | Maximum Modulation Frequency (cps) |
|---|---|---|---|---|
| Low Band | Intermediate Band | Wide Band | | |
| 1 7/8 | | | 1,688 | DC - 313 |
| 3 3/4 | 1 7/8 | | 3,375 | DC - 625 |
| 7 1/2 | 3 3/4 | | 6,750 | DC - 1,250 |
| 15 | 7 1/2 | 3 3/4 | 13,500 | DC - 2,500 |
| 30 | 15 | 7 1/2 | 27,000 | DC - 5,000 |
| 60 | 30 | 15 | 54,000 | DC - 10,000 |
| 120 | 60 | 30 | 108,000 | DC - 20,000 |
| | 120 | 60 | 216,000 | DC - 40,000 |
| | | 120 | 432,000 | DC - 80,000 |
| | | 120 | 864,000 | DC - 160,000 |

| Tape Speed (ips) | Carrier Center Frequency (cps) | Maximum Modulation Frequency (cps) |
|---|---|---|
| Video Band | | |
| 3 3/4 | 31,250 | DC - 12,500 |
| 7 1/2 | 62,500 | DC - 25,000 |
| 15 | 125,000 | DC - 50,000 |
| 30 | 250,000 | DC - 100,000 |
| 60 | 500,000 | DC - 200,000 |
| 120 | 1,000,000 | DC 400,000 |

3.2 Wide Band (±40%) FM (Continued)

Advantages of the frequency modulation recording process include the ability to record low frequencies down to DC, freedom from tape drop-outs, and excellent ability to accurately preserve the wave form of a recorded signal.

The prime disadvantage of FM recording is that it offers less efficient utilization of the tape. Approximately ten times the tape speed is required for a given upper-frequency limit.

FM record amplifiers (VCO) such as the Leach Model AR-105 are available and permit deviations of ±40% of center frequency without sacrifice of linearity. Wide band record amplifiers are generally designed to accept 5 volt p/p data signals for full bandwidth modulation. For low level inputs of 10-20 mv, the Leach Model AR-116 FM Record Amplifier should be used.

3.3 Flutter

Flutter has been mentioned briefly above several times because of its adverse effect on FM data. A definition of flutter and some discussion of practical measurement and compensation techniques is in order.

Velocity variations that are uniform across the tape are properly called FLUTTER. Measurement methods, generally include a certain amount of non-uniform velocity variations as well. The term "FLUTTER" is derived from the original definitions of motion irregularities in sound recording equipment. "WOW" was used to define speed variations at a rate of a few cycles/second, and "FLUTTER" to describe those of a higher frequency. The terms are phonetic descriptions of the different effects upon the ear, depending upon the frequency or rate of the speed variation. "WOW" no longer has any meaning in instrumentation recording.

Flutter arises from numerous sources in the tape transport mechanism. Obviously, any eccentricities in the capstan and any imperfections in its drive system will produce non-uniform velocity of the capstan surface with corresponding variations in tape velocity. The manufacture of tape transports hold all these imperfections to a minimum, however, many times the flutter is introduced into the tape transport by the particular environment in which it is located.

### 3.3.1 Flutter Specification

The proper technical description of flutter for specification purposes is very important. The effect of flutter depends upon the recording technique used. In audio equipment, the rms value of the flutter over a restricted band of frequencies (generally about 0.5 to 300 cps) is usually used as the flutter specification. This is not adequate for instrumentation equipment because flutter components up to the maximum data frequency covered by the system are important.

The flutter spectrum of a well-designed machine is a combination of small sinusoidal components and a more or less uniformly distributed noise signal. With this type of flutter waveshape, the peak or peak-to-peak value is a more useful description than the rms value and is therefore a better basis for predicting the effects of the flutter on the data. Peak-to-peak flutter is usually 4 or 5 times greater than the rms measurement.

### 3.3.2 Flutter Measurement

Flutter is measured by means of an FM discriminator. A known stable frequency must be recorded on the tape. On playback, the reproduced carrier is passed through an FM discriminator. The output is a direct measurement of the flutter. The frequency of the recorded carrier must be 5 to 10 times the maximum flutter frequency to be measured. When testing audio equipment, a carrier of 3 KC is used to measure components from DC to 300 cps. This flutter measurement is adequate for audio (voice and music) only.

For measurement of flutter components up to 10 KC at tape speeds of 60 ips, a carrier frequency of 50 kc or more is necessary. An FM discriminator of the type normally used for reproduction of wide band data can be used to recover the average and instantaneous frequency variations of the reproduced signal. Tape transports operating at 60 ips have relatively low flutter due to inertia of the high speed revolving components. Low speed tape transports are more susceptible to speed changes. A tape transport should be flutter checked at the speed at which it is intended to record data.

### 3.3.3 Flutter Compensation

Because flutter is the prime source of noise in FM system, it is important to investigate the means of correcting for flutter error. Present day tape transport designs are such that long term speed stability is no longer a problem. Electronic compensation systems have fast response and will compensate well throughout the entire carrier bandwidth. Such systems will eliminate the first order noise introduced by the flutter and make system performance relatively insensitive to tape transport performance, thereby lightening maintenance problems with respect to the tape transport. Compensation also makes the system DC zero independent of tape speed, so that elaborate and expensive speed control systems can be dispensed with in most applications when time base is recorded with data.

The simplest form of compensation, applicable to wideband FM carrier recording, comprises the recording of a stable frequency (preferably equal to the carrier or higher) reference signal on one tape track. Any frequency modulation of the carrier upon playback is proportional to tape speed errors. This error signal may be extracted from this reference channel with a conventional wide band FM data discriminator during playback. This error signal is equal in phase and amplitude to the data error signal if the reference frequency is equal to the VCO center frequency and the discriminator are alike. The error signal can be subtracted from the data signal on playback with a conventional differential DC amplifier. Error reductions of 10:1 are readily accomplished with this technique. In a wide band FM system where 2 interlaced head stacks are used, it is recommended that a reference carrier signal be placed on one track of each head stack.

When narrow band FM recording is used, errors due to flutter become almost prohibitive and compensation is very valuable to maintain signal-to-noise ratios and hold stable DC zeros. Compensation techniques for multiplex carriers are somewhat more complex than that for wideband FM. The principle of error subtraction applies to narrow band FM as well as to wide band FM. However, the error signal of a reference carrier is fixed at any given instant but the error signals of the various data channels are dependent upon the frequency response of each channel. In order to achieve all the advantages of compensation, the compensation channel must pass all frequencies from DC up

to the maximum data frequency that can be handled by the best signal channel.

Relatively complex circuits are required by the different time delays of the bandpass filters used to separate the individual carriers from the multiplexed signal. The compensation signal for each channel must be delayed by an amount equal to the signal delay in the bandpass filter for that channel. Thus, it is necessary to provide for a series of time delay networks and low pass filters in the compensation channel. On the other hand, the compensation signal can be multiplexed on the same track with the data signal carrier, thereby eliminating any random phase errors between tracks and improving the precision of the compensation signal.

### 3.3.4 Flutter under Dynamic Environments

Flutter in any tape transport mechanism is severely increased when it is subjected to shock and vibration environments. There is a direct relationship between the magnitude of the exciting forces and the amplitude of the flutter. This makes a tape recorder a good transducer -- many customers have accurately estimated shock and vibration environments from the measurement of flutter produced.

FM data is degraded the most by flutter, but is frequently used in severe environments anyway for its DC response. Direct or AM recording is also degraded by flutter, which distorts both the data frequency spectrum and amplitude. Flutter affects digital recording the least, particularly PCM or phase coded digital data. This is one of the reasons why digital recording is becoming the most widely used method of data collection.

Flutter cannot be entirely eliminated, but can be reduced by tape transport design and by isolation mounting. An effective isolator adds considerable size and weight to a tape recorder, and is a poor solution at best. Leach has been very successful with transport designs for low flutter in severe dynamic environments. Leach recorders are designed with small, lightweight mechanisms, yet are rigid and precise. Reels are as small as possible, since they are the most massive moving parts and therefore major flutter contributors. The MTR-3200 operates successfully hardmounted in rough vibration and shock environments largely because it mounts 8 inch reels rather than 10-1/2 or 14 inch reels.

## 4.0 PULSE DURATION MODULATION

The frequency division multiplexing technique described in Paragraph 3.1 is based on recording a number of signal channels on a single recorder track by sharing the available frequency spectrum among the signal channels. There is a second technique to accomplish a similar result in which "time" can be shared between a number of channels of signal information. This technique is called time-division multiplexing (PDM) and requires an instantaneous sampling of a number of signal channels on a sequential basis. Data handling techniques discussed in previous paragraphs all depend upon continuously recording each instantaneous value of the data. It is possible, however, to sample the data at uniformly spaced discrete intervals, record only the instantaneous values at the time of sampling, and then reconstruct the original signal on playback by passing the discontinuous readings through an appropriate filter. An accurate reproduction of a sine wave can be reconstructed using as few as six samples per cycle. Figure 5 traces signal flow and processing of sine wave data. This technique is equally valid for non-sinusoidal signals, provided the sampling rate is at least six times the highest significant frequency component of the signal.

When a data signal is sampled at discrete intervals, it is possible to use the time between these sampling intervals for the purpose of other data signals. This is most conveniently accomplished using a rotating mechanical commutator or a solid state electronic switching commutator. A standard for telemetry and tape recording has been set by the Inter-range Instrumentation Group. The IRIG standard for PDM has been set at 900 SAMPLES PER SECOND. Any combination of parameters (such as 90 parameters at 10 samples per second, 45 x 20, or 30 x 30 etc.) may be used so long as the 900 samples per second is maintained. The purpose for establishing a standard was to insure that the playback ground station would be capable of decoding the multicoded signal. Two contracts of the commutator are used for frame synchronization pulses. These synchronization pulses are used to correlate the ground station decommutator with the data recording commutator. Two other contacts of the commutator are used for zero and full scale calibration references, thus a calibration each revolution.

The outputs from the commutator are pulse amplitudes. The pulse amplitudes cannot be recorded directly on tape as the amplitude instability would degrade the data. Therefore, the signals are passed through a keyer which converts varying amplitude signals into constant amplitude signals with varying pulse widths, these pulse widths being directly proportional to the pulse amplitudes. These square wave pulse widths are differentiated in the PDM record amplifier and the differentiated spikes are recorded directly on the tape. The distance between the spikes is directly proportional to the amplitude of the data sample.

## 4.0 PULSE DURATION MODULATION (Continued)

A 1 cps signal from the transducer is sampled 10 times per second by a 90 x 10 commutator. The resulting amplitude pulses are biased positive within the keyer and then keyed to pulse widths, or pulse durations. The pulse durations are differentiated within the PDM record amplifier and then applied directly to the record head. The playback process is the inverse of the sequence described.

The prime advantage of PDM is the ability to handle a large number of simultaneous channels of information. Example: Using a 10 RPS 90 contact commutator, it is possible to record 86 channels of data and 4 channels of calibration and frame synchronization on one track of tape. With a 14 track recorder, it is possible to record 1204 channels of data. High accuracy is made possible by the self-calibrating feature. PDM offers relatively high signal to noise ratios due to the narrow signal frequency bandwidths involved.

The most notable disadvantages of the PDM process are the limited frequency response of each channel; less efficient utilization of the tape and the increased complexity of the auxiliary electronic equipment, such as commutators, keyers, amplifiers and filters.

## 5.0 PULSE CODE MODULATION DIGITAL RECORDING

The application of tape recorders with digitized data is of growing importance as a result of the widespread application of digital computers. In the digital recording process, a sampling technique similar to that used with PDM is applied to measure a varying signal. The sampled readings are converted into a code consisting of a series or group of binary digits. This conversion and subsequent processing of data is known as pulse code modulation (PCM).

In the digital data recording system, the usual mathematical system is the binary. The "bit" is the fundamental unit of the binary system and may be either one or zero. The binary system is a numbering system with a base of 2 instead of the base 10 with which we are most familiar. The base of 2 was chosen because arithmetic operations must be related to circuit capabilities and most conventional switching circuit elements will operate in only 2 states (on or off).

Digital recording is accomplished by magnetizing the tape to saturation in either of its two possible directions (+ or -) at discrete points along its length. Thus, there is only one of two states of magnetization at any point on the recorded tape, namely, saturation in one direction (+) or saturation in the opposite direction (-).

## 5.0 PULSE CODE MODULATION DIGITAL RECORDING (Continued)

Any one of several basic techniques may be used for recording binary digits. Several representative methods are explained below, and shown in Figure 5.

### 5.1 Return to Bias (RB)

The tape is magnetically biased to a predetermined level in one direction (-), and ones are recorded by magnetizing the tape in the opposite polarity (+). After each pulse for a one, the tape returns to the bias condition. A separate clock is required for readout.

### 5.2 Return to Zero (RZ)

Here the tape is normally in its neutral (zero) condition. Ones and zeros are assigned opposite polarity (+) or (-) and a bit or pulse is recorded for each digit. Return to the neutral state occurs after each pulse. Clock is contained in the code.

### 5.3 Non-Return to Zero (Change)

In NRZ (C) recording, the tape is always saturated in one direction or the other, one direction for logical "one" and the other for logical "zero". This is the format most often used by digital computers. A separate clock is required for readout.

### 5.4 Non-Return to Zero (Mark)

NRZ (I) differs from NRZ (C) recording in that polarity is changed each time a one is recorded and no change occurs for a zero bit. The NRZ (I) is the most widely used in digital recording systems, and appears to offer the best compromise between accuracy, simplicity, reliability and compatibility. A separate clock is needed for readout.

### 5.5 Manchester Coding

Manchester coded recording uses a polarity change for all bits, both ones and zeros. The direction of polarity change determines whether a bit is a one or a zero; thus for a sequence of ones or zeros, an extra return pulse is needed between bits. This method is sometimes called bi-frequency coding, is similar to RZ, and contains no clock.

## PCM CODING TECHNIQUES

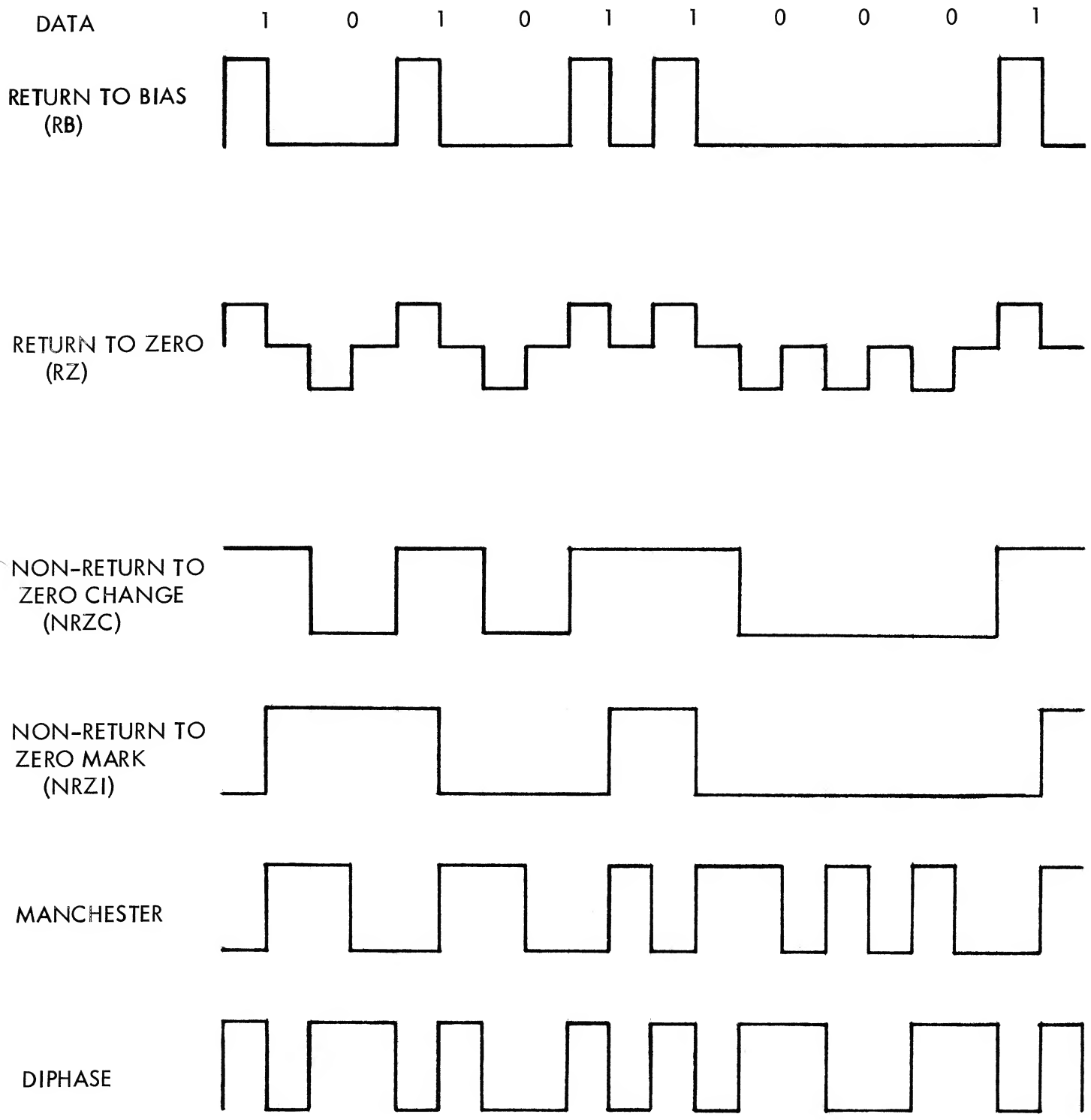



FIGURE 5

## 5.6 Bi-Phase Coding

Bi-phase coding is very much like Manchester, with either one or two pulses per bit recorded. A polarity direction change always occurs at the beginning of each bit cell; in addition, there is a direction change in the middle of the cell if the bit is a one, and no transition in the middle for a zero. This method is similar to NRZ (I), but contains the clock.

In some ways, the digital process is a simpler one than those previously discussed and presents fewer design problems. The record (write) and reproduce (read) amplifiers can be quite elemental. The speed stability of the transport is not as important, since relatively large amounts of flutter can be tolerated without affecting the recording accuracy. Other problems arise, however, which become more important in digital recording. Sensitivity to tape drop-out error is the most obvious one. Because all information is contained in the presence or absence of pulses, the generation of spurious pulses caused by the tape imperfections cannot be tolerated. For this reason, special precautions are taken in the selection of tape intended for digital recording.

One of the safeguards used to eliminate errors or drop-outs is redundancy. The same information is recorded twice on parallel, but separated, tracks on the tape. A second scheme is the use of a parity check, in which one track on the tape is reserved for a pulse derived from the pulses being recorded simultaneously on the other tracks. A parity pulse is recorded of such a polarity that the sum of all "one" bits on playback (including the parity bit) will be an odd number. Equipment designed to check "one" bit totals on reproduction will register an error if one or any odd number of the bits are lost causing the total to be an even number.

This system will not detect two simultaneous or any even number of errors. Other parity systems of greater complexity may also be used.

Digital magnetic tape recording has advantages that place it far ahead of data storage mediums, such as punched cards or punched tapes. The greatest advantage is a high data transfer rate. For example, the speed with which information can be "read off", or "written on" the tape far exceeds that available with most other media. Another advantage is the high density data storage. A 2400 ft. roll of one inch wide magnetic tape will store as much or more digital information as can be placed on 60,000 punched cards or 50,000 feet of punched paper tape.

## 5.0 PULSE CODE MODULATION DIGITAL RECORDING (Continued)

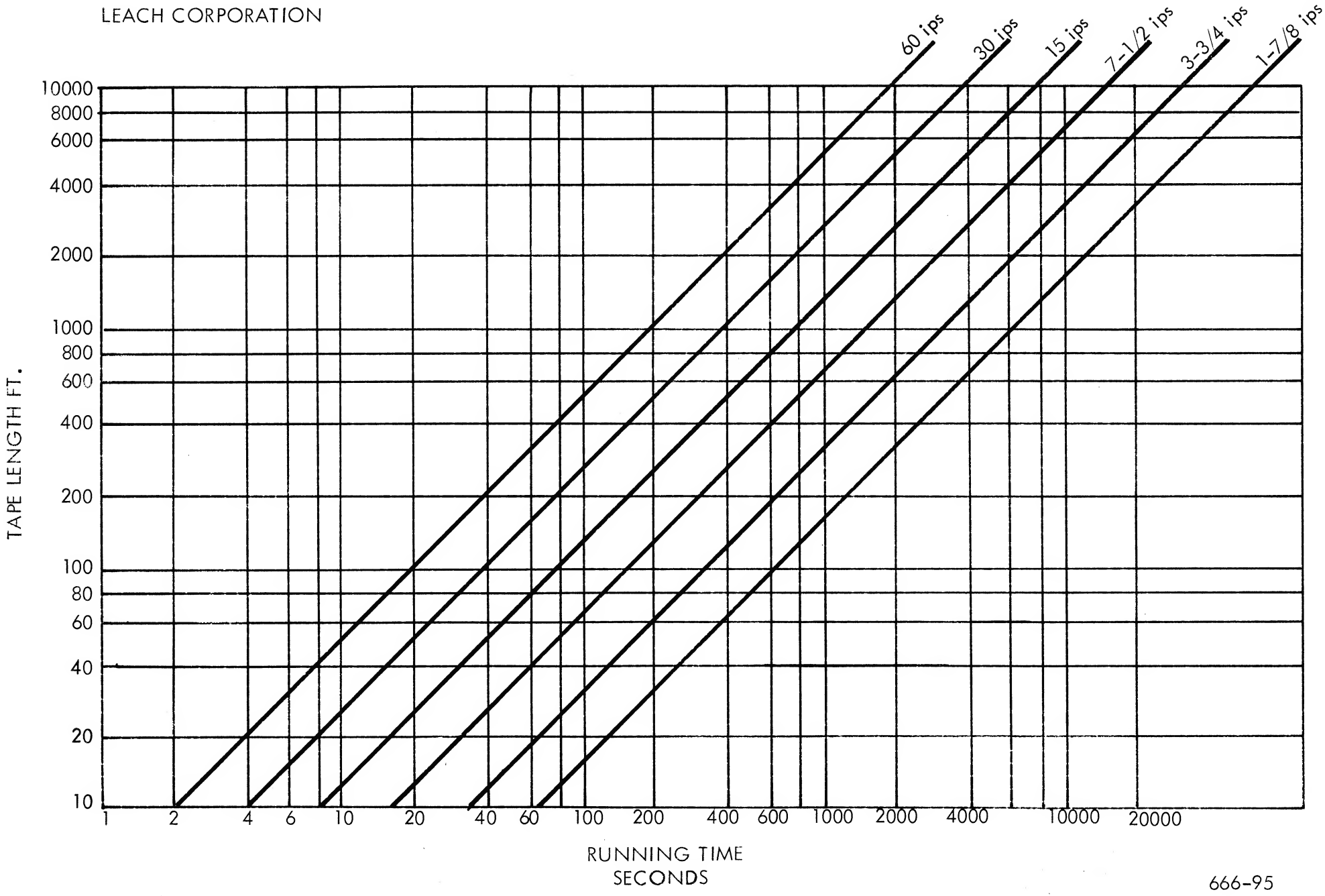
The major advantages of the digital recording process include the inherent capability of extremely high orders of accuracies, relative insensitivity to tape transport speed instabilities; simple record and reproduce electronic circuitry and compatibility with digital computers. Its disadvantages include poor tape economy, the requirement for special digital transducers or analog to digital converters; and relatively heavy dependence upon tape quality.

# RUNNING TIME VS. STANDARD TAPE SPEEDS

## FOR LEACH CORPORATION RECORDERS

| Speed | MTR-3200 2250' | MTR-2100 (2110) 1890' | MTR-1200 750' | MTR-362 75' |
|---|---|---|---|---|
| 120 | 3 m 45 s | 3 m 9 s | 1 m 15 s | 7.5 s |
| 60 | 7 m 30 s | 6 m 18 s | 2 m 30 s | 15 s |
| 30 | 15 m | 12 m 36 s | 5 m | 30 s |
| 15 | 30 m | 25 m | 10 m | 1 m |
| 7.5 | 1 hr | 50 m | 20 m | 2 m |
| 3-3/4 | 2 hr | 1 hr 40 m | 40 m | 4 m |
| 1-7/8 | 4 hr | 3 hr 20 m | 1 hr 20 m | 8 m |
| 15/16 | 8 hr | 6 hr 40 m | 2 hr 40 m | 16 m |

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